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The Reliability of Combustible Gas Alarms

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SAFETY is one of the most important factors in the design and operation of a modern-day plant. In striving for improved conditions, more and more consideration is being given to safety devices of one sort or another. One of these devices is the combustible gas alarm. This instrument is used for the protection of life and property in any area where a flammable mixture of a combustible vapor and air might be formed, the burning or explosion of which would be disastrous or, at best, undesirable. The device serves this protective function by continuously sampling the air and analyzing it for combustible concentration. According to the adjustment of the device and to the circuit arrangement, it may be made to sound an alarm at some concentration, and to shut down the operating equipment and perhaps actuate a fire-control system at some higher concentration. It is evident that there are many applications for a combustible gas alarm that would operate dependably.

In considering the advisability of purchasing any one of the available commercial instruments, the General Motors Research Laboratories tested seven different alarms of the non-portable, continuous-sampling type submitted by interested manufacturers. In testing each of the instruments, an attempt was made to determine whether it would be reliable under actual operating conditions. It is not the purpose of this paper to recommend any specific instrument but, rather, to present some typical results obtained in these tests to show the range of results one might expect to obtain with a similar assortment of instruments. Only one instrument of each make and model was tested so that no idea was gained of the variation from one alarm to another of the same make and model. The results should be interpreted accordingly. However, it should be added that each manufacturer was advised of any deficiencies discovered in his equipment and was given opportunity to make any reasonable effort to eliminate them during the tests.

Presented at a Joint Session of the American Industrial Hygiene Association and the American Conference of Governmental Industrial Hygienists, Chicago, Illinois, April 27, 1954.

Principle of Instrument Operation

BEFORE looking at the test equipment, methods, or results, the principle of operation of the instruments will be considered. In Fig. 1 is shown a schematic diagram of the main components of a typical alarm. At the upper left is the sealed reference cell containing a heated platinum filament and combustible-free air. At the upper right is the active cell containing another

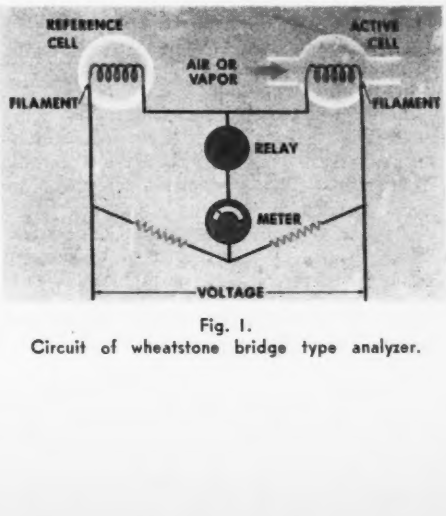

Fig. 1.
Circuit of wheatstone bridge type analyzer.

heated filament similar to that in the reference cell. The sampled air is drawn through the active cell by a pump not indicated in the figure. Any combustible vapor in the air being sampled reacts with the oxygen present, when it comes in contact with the hot platinum filament. This results in an increase in the filament temperature and, therefore, an increase in the filament resistance. This resistance increase results in a change in the current in the Wheatstone bridge circuit formed by the two filaments and two resistors. This change is registered on the meter which is calibrated in terms of a percentage of the lower explosive limit* or percent L.E.L. The relay may be set to trip at some percentage, to sound an alarm, stop machinery or actuate fire-control equipment.

Test Equipment

IN ORDER to evaluate the instruments, it was decided to determine periodically their response to a combustible mixture of known composition. Included in the first test setup were an air-flow system, a fuel-flow system, a mixing chamber, a timing and recording unit and a suitable arrangement of flow control valves.

The air-flow system used was one described by Cornelius and Caplan[2] in an SAE paper entitled "An Improved System for Control and Measurement of Air Consumption in a Single-Cylinder Engine." In this system, the principle of critical flow is utilized so that variations in downstream pressure have no effect on the mass rate of flow. The system was calibrated by use of calibrated orifice plates as described in the reference previously noted. This system has been used in a number of single-cylinder engine studies in the General Motors Research Laboratories and has been proved accurate and dependable.

The fuel-flow system is illustrated schematically in Fig. 2. A constant speed motor and gear train was used to drive a spindle around which was wrapped a wire. As the spindle turned, a counterweight was lifted at one end of the wire and an accurately machined plunger lowered at the other end through a mercury seal into the liquid fuel

*"The lower (explosive) limit corresponds to the minimum amount of combustible gas . . . capable of conferring flammability on the mixture."[1]

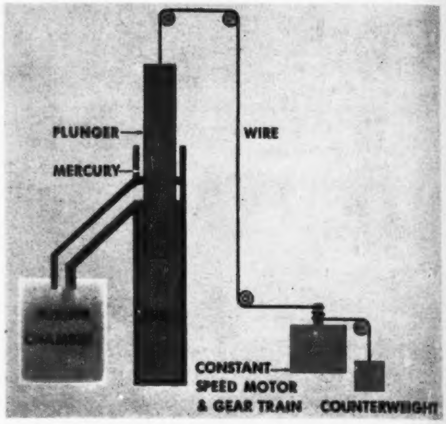

Fig. 2.
Positive displacement liquid metering device.

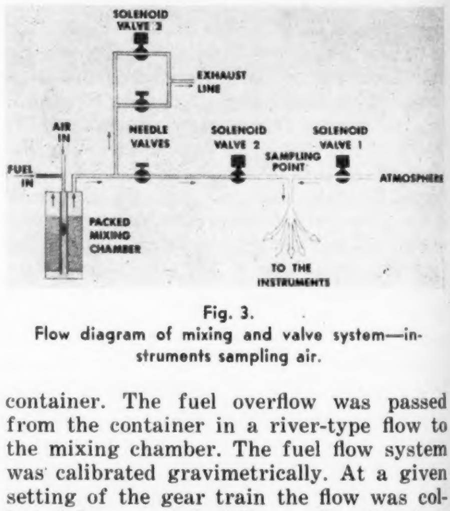

Fig. 3.
Flow diagram of mixing and valve system—instruments sampling air.

container. The fuel overflow was passed from the container in a river-type flow to the mixing chamber. The fuel flow system was calibrated gravimetrically. At a given setting of the gear train the flow was collected for a period of time and weighed. A consideration of the density permitted conversion to a volume basis.

The flow diagram of the mixing and valve system as set for sampling of combustible-free room air is shown in Fig. 3. In the lower left corner is the mixing chamber to which fuel and air were passed at known rates of flow. Solenoid valve No. 2 was closed so that the air-fuel mixture flowed upward and out the exhaust line. This continuous flow arrangement was necessary to permit known equilibrium air and fuel flows

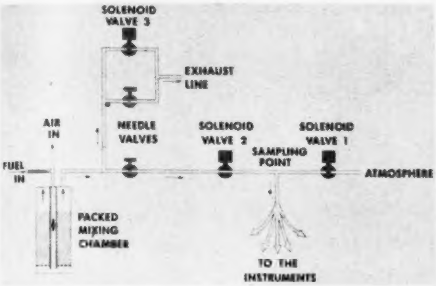

Fig. 4.
Flow diagram of mixing and valve system—instruments sampling mixture.

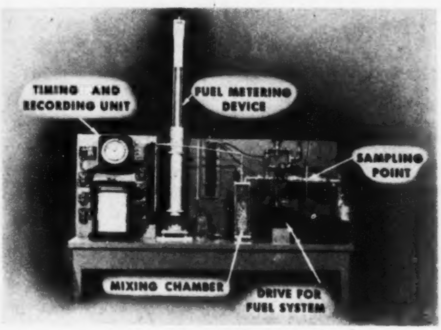

Fig. 5.
Test equipment.

to be established and maintained. Solenoid valve No. 1 was normally open so that room air was sampled by the instruments, all of which were attached to the same sampling point.

The situation shown in Fig. 4 existed when the instruments were made to sample the known mixture from the mixing chamber. Valve No. 1 was closed and No. 2 opened. The two needle valves and solenoid valve No. 3 were installed for pressure control purposes.

A picture of the test equipment is shown in Fig. 5. Shown are the fuel metering cylinder and plunger, the drive box for the fuel system with the drive spindle, and wire running to a counterweight at one end and the plunger at the other. The fuel flowed from the metering cylinder to the mixing chamber through the sloping tube connecting the two. Air was introduced at the pipe tee just above the mixing chamber. The air and fuel flowed to the bottom of the mixing chamber, up through the ceramic packing and out to either the exhaust line or to the sampling point depending on the settings of the solenoid valves. All of the lines to the instruments were attached at a point between the two solenoid valves. Twenty-five feet of copper tubing of the size recommended by the manufacturer was used between the sampling point and each instrument.

At the left in Fig. 5 is the timing and recording unit with which the solenoid valves could be actuated to introduce either air or the air-fuel mixture to the instruments according to a predetermined cycle. This portion of the test equipment was installed during exploratory work in an effort to accelerate the test program. It was found, however, that the results obtained with the cycles of short duration did not correlate with those obtained with the cycles of longer duration which are believed to correspond more closely to actual operating conditions. Therefore, for the results reported here the solenoid valves were operated with a hand switch on a cycle which will be discussed later.

Test Procedures and Fuels

THE TEST cycles and fuels are listed in Table I. The instruments were in operation continuously for from one to two months in each test. The cycles were identical for the first three fuels. This cycle was modified somewhat for the last one.

TABLE I.
TEST CYCLES AND FUELS

Test	Cycle	Fuel
1	Long	n-pentane
2	Long	natural gas
3	Long	n-pentane plus TEL
4	Modified Long	n-pentane

For the first test normal pentane was used in an effort to simulate the results of a spillage of gasoline or jet fuel, since the most volatile ends of these fuels are comprised largely of this material. The test cycle used with this and the next two fuels has been called the long cycle. This name was adopted primarily to differentiate this type of sampling from the short cycle used in earlier exploratory tests. Room air was sampled continuously except for two brief periods of about five minutes each per week,

one on Monday and one on Thursday, when the response of each instrument to an air-fuel mixture of known concentration was checked. The zero reading was noted daily and, if the zero had drifted, it was adjusted on Monday before the response check was made. The flow rate was also noted daily and adjusted, if necessary before the response reading on Monday. Additional adjustments of zero or flow were made at times other than Monday, when there was such extreme departure from the desired settings that additional readings would be meaningless.

For the second test, natural gas was used as a test fuel to simulate conditions in which this or a similar fuel, such as liquified petroleum gas, is used. The fuel metering system shown in Figs. 2 and 5 was replaced with a natural gas line, a control valve and a calibrated flow meter.

The third test was made to check the effect of the presence of tetraethyllead in such fuels as automotive and aviation gasolines. Normal pentane containing 6.0 ml of tetraethyllead per gallon as yellow-mix Ethyl fluid was the fuel and the long cycle again was used.

In the fourth test the long cycle was modified slightly in order to simulate conditions near a paint spray booth or in a paint mixing room. For this test a low concentration of normal pentane in air was fed to the instruments for eight hours each working day. As in the long cycle the response to a higher concentration was checked twice a week. Other observations and adjustments were made as described in the long cycle procedure.

Results

THE RANKING of the instruments was essentially the same in all four types of sampling. If an alarm was satisfactory for one type, it was satisfactory for the others. It was also true that if an alarm was unsatisfactory under one of the four types of operation, it was unsatisfactory under the other three. It should be pointed out, however, that when leaded fuels were being sampled, an increased amount of maintenance and attention, increased filament temperatures and special components were required for successful performance.

Nevertheless, the results with the four types of procedure were similar enough so that it will suffice to examine only some of the typical results obtained in the unleaded fuel operation. Some instruments performed well, others poorly. Results will be presented for three representative instruments, one of which was rated good, another fair, and the last poor.

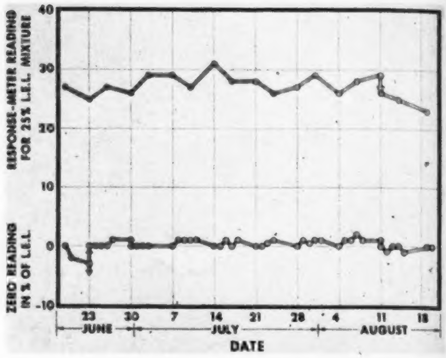

Fig. 6.
Results for "Good" instrument.

"Good" Instrument

IN FIG. 6 are shown the results for the instrument which was rated good. The instrument meters are calibrated in terms of percentage of the lower explosive limit, or % L.E.L., which is used as the "Y" coordinate in the figure. Vertical lines are drawn for each Monday.

The zero-reading characteristic for this instrument is shown in the bottom curve. It would be ideal if the instrument would read zero from week to week and month to month when combustible-free air is being sampled. When the test was initiated on Thursday, the 19th of June, the instrument was adjusted to read zero when combustible-free air was sampled. On the next day it was found that the reading on clean air was −2, and on Monday, the 23rd, it was −3 or lower. The needle was actually bearing on a limit stop at the far left of its travel as indicated by the downward-pointing arrow at the −3 point. At this time the zero was readjusted as indicated by the upward-pointing arrow. Evidently the instrument operation was stabilized in this first week as shown by the fact that the zero reading varied only from −1 to +2 there-

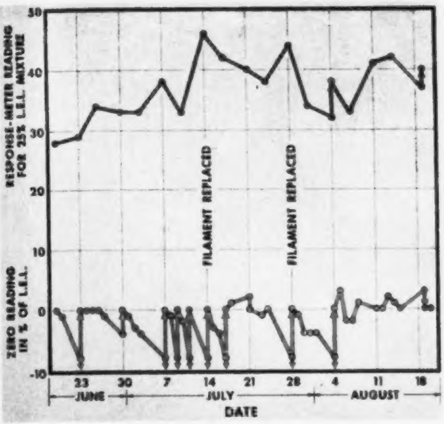

Fig. 7.
Results for "Fair" instrument.

after. This machine had the best zero stability of any of the seven tested.

The second characteristic used in evaluating the instrument reliability was response accuracy. Again, ideally, the instrument should indicate the true combustible concentration indefinitely. In the upper curve are shown the response readings of this instrument. In order to obtain the data for this characteristic, the fuel and airflows were arbitrarily set to give a 25% L.E.L. mixture which was fed to the instruments for a brief period twice weekly, on Mondays and Thursdays. At the beginning of the test, the response varied between 25 and 27% L.E.L. The maximum and minimum responses in the two-month period were 31 and 23%. The two points on the 11th of August indicate that a response reading was taken both before and after the zero was adjusted. On that day the zero was 1% high initially and the corresponding response was 29%. When the zero was readjusted, the response dropped to 26%, only 1% from the true value. The response with this instrument was as good as that of any of the instruments tested and is considered acceptable.

"Fair" Instrument

IN FIG. 7 are shown the zero and response readings of the instrument which was rated fair. With this instrument the zero stability was not nearly so good as with the previous one. On June 23 the reading had dropped to −8 or lower as indicated by the arrow which shows that the meter needle was bearing against the low limit stop. This same drop occurred eight times during the test period. This is the most serious type of zero drift. With an upscale drift, the worst that can happen is a false alarm or unnecessary stoppage or fire control actuation. With a downscale drift, however, there is the risk that combustible gas would accumulate and a disaster occur with the zero reading so low that there would be insufficient response even to sound an alarm. For one particular week the cumulative downscale zero drift was at least 24% of the L.E.L. and probably much more. At two points in the testing, on July 14 and 28, the filaments were replaced because it was no longer possible to adjust the zero. The reason for the improvement in the zero stability subsequent to August 4 is not known.

The response stability for this instrument was little better than the zero stability. The Monday response readings were taken in every case after readjusting the zero. As indicated by vertical arrows on August 4 and 19, readings were taken before as well as after zero adjustment. The maximum and minimum responses were 46 and 28. As in the case of the zero stability, the response stability improved after August 4, the response varying from 42 to 33. However, few of the readings were close to the true value, 25. In a plant installation where stoppages are costly, an instrument giving several false alarms because of this type of response would soon be removed by the management.

"Poor" Instrument

IN THESE tests the performance of the "poor" instrument was so bad that it was impossible even to obtain continuous zero and response stability data. There were a number of faulty components in the instrument. Several new filaments were unusable. The filaments were difficult to install properly. Two of them burned out during this long cycle test period. One switch did not operate correctly. A meter in the circuit was extremely sluggish. It would have been a full-time job for a man to regulate the flow of the air through the instrument. On many occasions the flow was adjusted to

the proper rate on one morning and found to be zero on the next.

Maintenance

THROUGHOUT the tests one very significant fact was made evident: These instruments cannot be installed, forgotten and then relied upon to give adequate protection. A regular inspection and maintenance program must be followed. It was indicated in the tests that this program should include a daily inspection, and adjustment if necessary, of the zero and of the flow rate. It seems advisable that a check of the response to a known air-fuel mixture should be made at least once weekly. Known mixtures of fuel and air are available commercially which may be used for this type of check or for future instrument testing.

Summary

AGAIN it must be emphasized that it is not the intent in this paper to recommend any particular instrument. In summary:

1. Several commercial instruments performed so poorly that they were judged unsatisfactory. Only two of the seven instruments performed well enough to be judged acceptable.
2. Even the best of instruments cannot be installed, put in operation, and forgotten, but a regular inspection and maintenance program must be followed.
3. Special precautions are required for satisfactory operation when leaded vapors are sampled.
4. It is believed, however, on the basis of the tests described above that there are good commercially available alarms which can be relied upon to detect combustible gas at the sampling point, provided an intelligent maintenance program is regularly followed.

References

1. COWARD, H. F., and JONES, G. W.: Limits of Flammability of Gases and Vapors. Bureau of Mines Bulletin 503, 1952.

2. CORNELIUS, W., and COPLAN, J. D.: *SAE Quarterly Transactions*, 6:4 (October) 1952.

Noise in Industry

THE SECOND INDUSTRIAL NOISE CONFERENCE sponsored by the Technical Committee on Noise in Industry of Associated Industries of New York State, Inc., was held at the Chamber of Commerce Building, Rochester, New York, November 9. DR. JAMES H. STERNER, Medical Director of Eastman Kodak Company, served as Conference Chairman with F. A. PATTY, Head of Industrial Hygiene, General Motors Corporation and DR. B. L. VOSBURGH, Manager, Health Services, General Electric Company, presiding. The following speeches were delivered at the conference: "What is Noise?"—DR. ALLEN D. BRANDT, Chief, Industrial Hygiene Engineering, Bethlehem Steel Company, Bethlehem, Pennsylvania; "Measurement of Noise"—DR. CHARLES R. WILLIAMS, Director, Applied Research, Liberty Mutual Insurance Company, Boston, Massachusetts; "Fundamentals of Hearing"—DR. C. STEWART NASH, Otologist, Rochester, New York; "Measurement of Hearing Loss—Practical Programs for Industry"— DR. ARAM GLORIG, Director of Research, American Academy of Ophthalmology and Otolaryngology, Los Angeles, California.

A New Electrostatic Sample Collector Permitting Direct Microscopic Examination

PAUL F. WOOLRICH, M.S., Salt Lake City

RECENTLY, a new electrostatic precipitator which collects samples on either glass slides or metal plates was reported in the literature.[1] In 1950, Bourne and Fosdick[2] reported the development of a method for collecting airborne dust on a hemacytometer cell utilizing electric precipitation. With dust deposition on glass slides, investigators are permitted direct microscopic examination of unaltered samples. Such samples are useful to determine some of the physical characteristics of airborne dust, such as particle-size and state of agglomeration.

Practically every industrial hygienist has available an electrostatic sampler. To make fuller use of this available equipment, a new sample collector has been developed whereby dust deposition is on glass slides. The collector is easily constructed of Plexiglass or Lucite, a 3-inch section of 1½-inch O.D. aluminum sampling tube, two 1 by 6-inch strips of aluminum, and some wire.

The center ionizing electrode designed for commercially available samplers is utilized with this new sample collector. As the dust deposition area has been greatly reduced by using slides rather than a cylinder, the air flow through the sampling head must be reduced for efficient deposition. A 2¾-inch metal lid from a shipping carton will easily slip over the exhaust portal of the sampling head.

By drilling holes in this lid, the air flow through the sample collector may be effectively reduced to 15-liters per minute with subsequent efficient dust removal when the precipitator is operated at 15,000 volts.

The relative efficiency of the sample collector can be readily checked microscopically. A lack of visible particle deposition on the suction end of the slide would appear to indicate efficient dust removal in the size range microscopically visible. No absolute efficiency checks have been performed inasmuch as the collector was not primarily designed for quantitative sampling, but to obtain samples for studying the physical characteristics of airborne dust.

To prevent arcing from the ionizing electrode to the cylinder adapter of the collector, the inside of the adapter may be lined with electric tape (dielectric over 7000 volts).

As a further measure to prevent arcing at the adapter, a portion of the ionizing electrode might also be wrapped with electrical tape.

The sketch (Fig. 1) and the following brief description are presented to serve as a guide in constructing the collector:

1—A 2-inch section of aluminum sampling tube which serves as an adapter to the sampling head. This section is cut such that—

2—Projects from (1) and is formed to shape around (3).

3—Constructed of three pieces of 3/32-inch Plexiglass, laminated together and a 1½-inch hole cut to receive the adapter. For structural strength, one of these pieces of Plexiglass is grooved to receive (4), (5) and (6), the collector framework.

4 and 5—Eight strips of 3/32-inch Plexiglass. Size: 6-3/32 by ⅜ inches.

6—Two pieces (the top and bottom of the

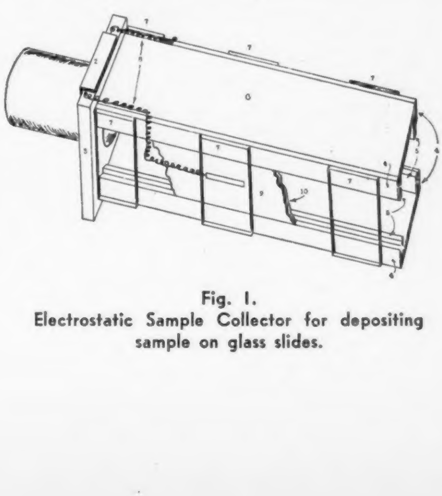

Fig. 1.
Electrostatic Sample Collector for depositing sample on glass slides.

collector) of 3/32-inch Plexiglass. Size: 6-3/32 by 1½ inches.

7—Six pieces of 3/32-inch Plexiglass. Size: 1 by 1¾ inches. These pieces are added for structural strength, to make an air-tight seal at (3), and to hold the wires (8) in contact with the aluminum strips (9).

8—Wires to carry the electrical current from the collecting electrodes (9) to (2) and the adapter (1).

9—Two one by six-inch polished aluminum strips (22-gage aluminum).

10—Two one by six-inch glass slides.

Discussion

AN ELECTROSTATIC sample collector has been developed for qualitative analysis of particulate matter deposited directly onto glass slides. It is hoped that the collector can ultimately be utilized in the measuring of particle diameter as a function of position on the slide.

This collector was utilized extensively under field conditions during the summer of 1953.

More specific information as regards the collector performance awaits further photomicrographic investigation of these samples.

References

1. HOSEY, A. D. and JONES, H. H.: Portable electrostatic precipitator operating from 110 volts A.C. or 6 volts D.C., *Arch. Ind. Hyg. & Occ. Med.*, 7, 49-56 (January) 1953.

2. BOURNE, H. G. and FOSDICK, L. B.: Collection of mist and dust for particle size measurement: electrostatic precipitation on hemacytometer, *Analyt. Chem.*, 22, 1563 (December) 1950.

Air Pollution Abstract

ATMOSPHERIC POLLUTION: CAUSES, EFFECTS AND PREVENTION. By A. PARKER in *J. Instn. Civ. Engrs.*, 3:99-124, 1954. In this valuable lecture the Director of Fuel Research, of the Department of Scientific and Industrial Research, reviews the problem of atmospheric pollution in Great Britain, concentrating on that due to the combustion of carbonaceous fuels. Current estimates of the cost of this pollution are £100-150 million per year; so the problem is one which justifies the attention paid to it. Over 200 million tons of coal and nearly 17 million tons of petroleum products are consumed annually to produce (in millions of tons per annum) sulphur dioxide 5.3, smoke 2.1, grit 0.6 and carbon monoxide 24.0. Smoke can be very materially reduced by more efficient combustion, especially in the home, and grit may be to a great extent eliminated in large plants by modern methods of flue-gas cleaning. Efficient combustion will reduce carbon monoxide a little but a great improvement must await advances in carberration in spark-ignition engines. The greatest need for smoke abatement (which may in turn reduce the harmful effects of sulphur dioxide) is an increased expansion of solid, smokeless fuels; this, in turn, requires a more intelligent integration of the use of coal for gas and electricity, and for direct combustion. Nor should the advantages, in suitable localities, of district heating be forgotten. Wet scrubbing of flue gases for the removal of sulphur dioxide can only be applied in the largest plants; there is hope that current investigations of flue-gas scrubbing with ammoniacal gas liquor may result in the development of an economical process. This authoritative and thought-provoking paper can be strongly recommended as giving a valuable conspectus of the current position in Britain. —PETER C. G. ISAAC, Newcastle Upon Tyne.

Radioactive Dust and Gas

IN THE URANIUM MINES OF UTAH

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LITTLE or nothing was known of the worker's environment in the uranium mining industry prior to a survey[1] made in 1950-52 by the U.S. Public Health Service. However, from the scanty amount of literature on the health aspects of uranium mining in Europe, it was known that many of the miners died in the prime of life with symptoms of damaged lungs and rapidly deteriorating health. Investigation proved the affliction to be malignant tumor of the lungs. Although the etiological agent has been attributed to various elements (cobalt, nickel and arsenic) rather high concentrations of radon from radioactive ores were present.

The 1952 Interim Report[1] showed for the mines studied on the Colorado Plateau, that the mine atmospheric concentration of radon and its decay products far exceeded the presently accepted threshold limit. In view of these findings and the fact that excessive amounts of chronic irradiation *per se* represent a health hazard regardless of whether or not it induces cancer, the Division of Occupational Health, Utah State Department of Health, made a study of all known actively producing mines in Utah during the summer months of 1953.

Nine of the mines (selected at random) were re-studied in December, 1953, since the natural ventilation of a mine is increased by the greater temperature differential existing between the mine air and outside atmosphere in the winter.

Presented at Fifteenth Annual Meeting, AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, Chicago, Illinois, April 29, 1954.

TABLE I.
DISTRIBUTION OF WORKERS UNDERGROUND FOR THE 75 URANIUM MINES SURVEYED IN THE SUMMER MONTHS 1953

Number Mines	Number Employees per mine
3	1
14	2
21	3
13	4
9	5
9	6
3	7
3*	over 10*

*A total of 65 employees in these three mines.

Uranium Mining Operations

THE URANIUM mining industry in Utah has transformed hundreds of miles of wasteland into a blooming desert enterprise. It has undergone a period of rapid expansion and few people outside of the industry realize its recent growth because the operations are so sparsely spread over such a large area of the State. To clarify the geographical distribution of these mines, we may group them into three large mining sections or districts, namely: (1) the Blanding-Monticello-Moab area in southeastern Utah near and along the Colorado State border; (2) Temple Mountain area about 50-60 miles south of Greenriver, Utah; and (3) the Marysvale area in central southern Utah.

Uranium mining operations do not differ appreciably from other non-ferrous metal mining operations, but they are usually not large scale operations. Most of the mines employ only a few miners—often not more than three or four (Table I). In general, the ore deposits have largely dictated the initial mine layout and development. The simple procedure is to follow the ore body through its many wanderings through tons of waste rock. The flat-

Fig. 1.
Uranium mining of flat-bedded deposits through horizontal drifts into side of cliff.

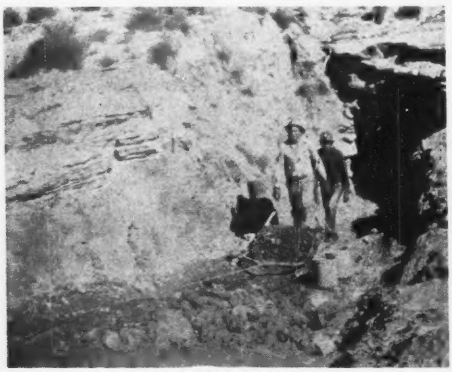

Fig. 2.
Slusher operation up an incline shaft.

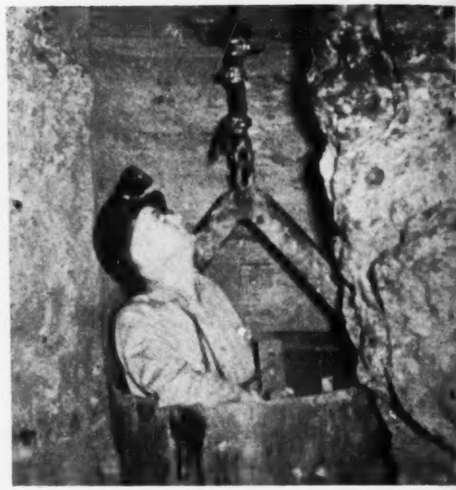

Fig. 3.
Bucket used in a Calyx Shaft for hoisting men, ore, and materials.

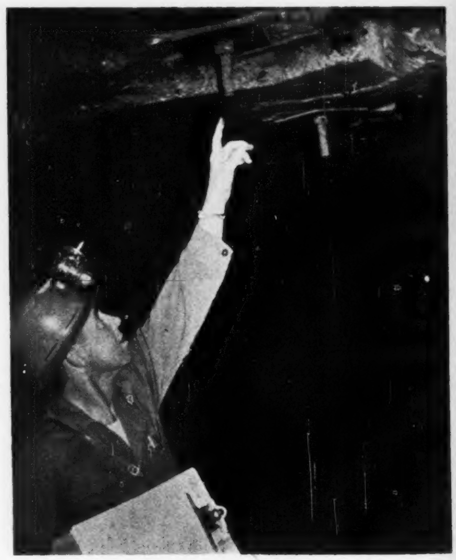

Fig. 4.
View of closely spaced roof bolting.

bedded deposits (Fig. 1) are mined through horizontal drifts, usually starting with a short level tunnel into the side of a hill or cliff. At other mines, shafts may be inclines (Fig. 2) varying from a few degrees to the vertical. In the Temple Mountain area eight or more mines have been started through a vertical shaft known as a Calyx Shaft (Fig. 3), a bore of 38-inch diameter through solid rock. The depth of these shafts is about 100 feet. The ore bodies in the Marysvale area are found in vertical fissures and the mining operations are carried on through inclined and vertical shafts to various horizontal levels below the surfaces and through many raises between levels.

A considerable amount of timber is needed in the Marysvale mines, but timber to any great extent is not required in most uranium mines, except at the portals, as the drilling operations are through solid rock. In the large Utex Exploration Company[2]

Fig. 5.
Horses and small carts are employed to remove ore from uranium mines.

Fig. 6.
Diesel shovel loader discharging ore into a truck.

mine located in the La Sal Mountains between Moab and Monticello, Utah, a modified room-and-pillar method of mining is employed, because of the substantial width and thickness of the ore deposit. Virtually no timber is required except at the vertical shaft (auxiliary man-way). In this mine, however, roof bolts (Fig. 4) on a 4-foot spacing pattern are being extensively used in the backs of drifts, rooms and stopes.

One may find the ore being trammed from the mines in small ore cars, often being pushed by hand to an unloading platform. In small operations, horses and small carts, and even wheelbarrows are employed to remove the ore (Fig. 5). Some of the mines have inclined chutes which run down

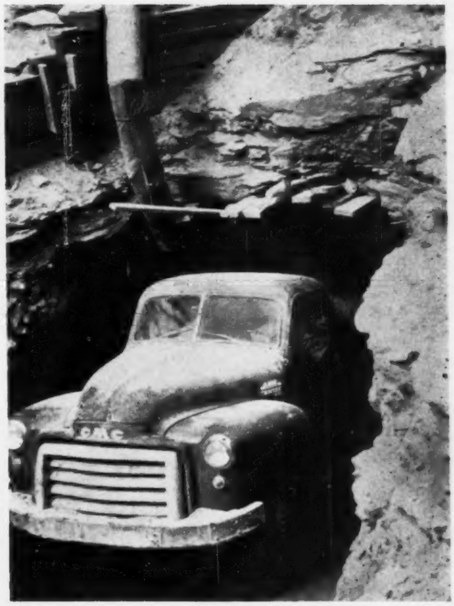

Fig. 7.
Diesel truck used for underground haulage; and ventilation piping.

the sides of cliffs to ore bins below. In the Utex Exploration Company mine,[2] the broken ore is loaded underground with an International TD-9 Tractor Loadover (Fig. 6). Then it is hauled to the surface up an inclined adit and dumped on the ore stock pile with a GMC diesel-motor tandem truck (Fig. 7). Several of the large mines have mucking machines, slushers and diesel-powered shovel loaders and locomotives for hauling the ore. Later the ore is dumped into trucks which transport the ore over rugged country usually to some processing mill; one mill is located at Monticello and another at Salt Lake City, Utah.

Survey and Sampling Procedure

With the assistance of the professional staff of the U.S. Public Health Service Field Station, Salt Lake City, Utah, four men,* three school teachers and one medical student, employed for this survey by Utah State Department of Health, were given

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*Jess Brown, Merrill Hill, Richard Neill and Lynn Robinson, all of Salt Lake City, Utah. During the summer months, 1953, the survey teams traveled over 13,900 miles.

Fig. 8.
Diesel caterpillar used for underground haulage; and ventilation fan at surface level.

an indoctrination course for a week covering pertinent and related subjects as shown in "Schedule of Instruction," Appendix I. The men worked in teams of two, and were accompanied by the author during the first week. Weekly conferences were held throughout the entire period of study.

Upon the arrival of a survey team at a mine, contact was made with the owner, lessee or operator to explain the purpose of survey and outline the procedure. After gathering the necessary data, such as ownership, location of the mine and number of persons employed underground, a tour was made through the mine. A sketch was drawn, indicating the mine layout and ventilation installations, (Note typical vent tube as in Fig. 8) with a general description of type of mining operations employed, including any observed gasoline or diesel-powered equipment operating underground. (In Utah, gasoline engines are not permitted underground, but diesel equipment may be operated with special written permission from the Industrial Commission of Utah for each piece of equipment and specific location.) Location of sampling stations and other miscellaneous information were also shown on the sketch.

The team then collected dust and gas samples at each working face of the mine, in the main haulageways, and at a few nonworking areas or dead-end drifts. Ventilation measurements were made at each sampling station with a velometer, a vane anemometer or by smoke tube method. Tests were made for carbon monoxide whenever operations indicated that CO might be present in the mine atmosphere from contaminated compressed-air lines or vent tubes or from gasoline or diesel-powered equipment found to be operating underground.

Sampling procedure for radioactive dust particles (RaA, RaB, RaC and RaC′) consisted of drawing air by means of a hand-cranked pump for five minutes through a one inch diameter millipore filter*[3] (contained in a special adapter) at a measured rate of 14-25 liters of air per minute (the range at which a working miner breathes).[4] After collecting the sample, the filter was taken outside the mine and the alpha activity was measured by a Juno Alpha, Beta, Gamma Survey Meter. This instrument had been previously calibrated against a laboratory counter so that the scale readings could be converted to alpha disintegrations per minute (dpm). The activity (dpm), as

*Trade names for molecular or membrane filters adopted by Lovell Chemical Company, Watertown, Massachusetts.

TABLE II.
AVERAGE CONCENTRATION RANGE ($\mu\mu$ c/l) OF RADIOACTIVE DUST PARTICLES (RaA, RaB, RaC & RaC′) FOR ALL THE FILTER SAMPLES AND FOR THE 75 URANIUM MINES SURVEYED IN UTAH, 1953

Average Concentration Range ($\mu\mu$ c/1)*	Number of Samples	Number of Mines (1)
0-100	49	21 (2)
100-1000	73	13
1000-2000	72	9
2000-3000	28	6
3000-4000	29	5
4000-5000	18	0
5000-6000	16	1
6000-7000	8	5
7000-8000	4	2
8000-9000	9	3
9000-10,000	5	0
10,000-20,000	49	6
20,000-30,000	15	1
30,000-40,000	14	1
40,000-50,000	4	1
50,000 or over	4	1
(55,000) 1		
(57,900) 1		
(67,000) 1		
(112,320) 1		
Totals	397	75

*$\mu\mu$ c/1—micromicrocuries per liter of air for the dust particles (RaA, RaB, RaC and RaC′).

Note: 1. Average concentration range is average of all samples for each mine surveyed.

Note: 2. Dust samples in six mines showed concentrations too low to be measured or not detectable.

measured by Juno readings, was extrapolated back to the end of the sampling period by use of correction curves, and since the sampling rate was known, values of radioactivity as micromicrocuries of radon daughters per liter of air ($\mu\mu$ c/1) were calculated.

To collect radon samples, the sampler drew air for a period of two minutes with the hand-cranked pump through glass flasks especially designed for this purpose by the U.S. Public Health Service Field Station. These flasks were forwarded to the Field Station for laboratory analyses.

Results of Radioactive Samples

A TOTAL of 397 millipore filter samples for radioactive dust (radon daughters) measurements and 116 flask samples for radon determinations were collected during the summer months, 1953. Table II shows the average concentration range of radon daughters for all the samples taken and for the 75 mines surveyed (mine concentration level is the average of all the samples in each mine). The median level of all of the filter samples was 2100$\mu\mu$ c/1. Fifty-four of these mines had an average concentration above the accepted threshold limits for radon degradation products (100$\mu\mu$ c/1) and 10 mines had concentrations which averaged above 10,000$\mu\mu$ c/1.

All of the filter samples in six of the mines demonstrated that concentrations of radon daughters were either too low to be measured or not detectable. In these six mines the mining operations were limited. It is presumed that the ore body had not been sufficiently exposed to produce a quantity of alpha radioactivity that could be measured by the sampling method employed. These mines had made no provision for any mechanical ventilation and the movement of natural air currents was negligible.

In general, the radon concentrations were of the same magnitude as the millipore filter samples which were taken in the same location at the same hour and date.

A total of 149 tests was made for carbon monoxide with an MSA CO Detector, but in only two mines did the atmospheric concentration exceed 100 ppm. It was noted that 12 mines employed diesel-equipment underground; one mine was using a gasoline engine sump pump; and two mines were practicing dry drilling. None of the miners were observed to be wearing respirators.

Ventilating Conditions

VENTILATION of any mine has to do with the coursing of air currents through underground openings. This may be partially accomplished by natural air currents, but auxiliary mechanical ventilation is also needed. The proper distribution of air underground demands careful thought and planning so that the air will reach the working face in sufficient quantity to provide good air and to remove at the same time the harmful dusts and other contaminants from the miner's breathing zone.

From this survey, it was apparent that the majority of mines had given little attention to adequate ventilation. In some instances air was being forced down churn-drill holes (usually 8-inch diameter), but the air was not reaching the working face area effectively. A few mines were using churn-drill holes as substitutes for ventilation raises, but most mines had not established any ventilation raises to provide for effective air courses. Such air courses would allow better air movement and would reduce to some extent the concentration level of radioactive dust particles, particularly in the main haulageways.

Of course, many of the mines are small, employing relatively few miners underground, and since they were practicing wet drilling as required by Utah law, excessive dust was not noted. Too, as most of the mines operate but one shift per day, some of the powder smoke, gases, and dust particles are removed during the night by natural ventilation and settling. However, because of the high concentrations of radioactive dust and gas found in these mines, it is evident that more consideration must be given to mine layout to provide for better ventilation practices.

Winter Versus Summer Conditions

IT WAS REALIZED that the temperature differential between underground and outside air is such that natural air currents in a mine would be greater in the winter. To learn what effect this increase in natural ventilation would have on the concentra-

TABLE III.
COMPARISON OF SUMMER AND WINTER CONCENTRATION OF RADIOACTIVE DUST PARTICLES (RaA AND RaC′) AND RADON GAS IN NINE URANIUM MINES SURVEYED IN UTAH (1953)

Mine Identity Code	RaA and RaC′ Summer μμc/l*	RaA and RaC′ Winter μμc/l*	RaA and RaC′ Reduction (%)	Radon Summer μμc/l*	Radon Winter μμc/l*	Radon Reduction (%)
HN-2	181(3)	122(7)	31	350(1)	167(3)	52
RB-2	419(3)	193(6)	54	330(1)	380(3)	12**
RB-31	14000(9)	3065(6)	78	10500(2)	4100(2)	61
RB-30	1551(8)	155(8)	90	1375(2)	435(2)	68
HN-36**	1097(12)	1164(6)	11**	483(3)	920(3)	19**
RB-27	1642(10)	602(5)	63	1650(2)	755(2)	55
HN-31	3008(14)	1370(7)	54	2858(4)	1410(2)	51
HN-35	3915(10)	961(8)	75	3350(2)	1110(1)	67
HN-32	1011(7)	354(8)	65	2030(3)	285(2)	86
Total number of Samples	76	61		19	20	

*μμc/l—micromicrocuries per liter of air. Concentration average for respective mines.
**Percent gain.
Note: Number of respective samples for each mine indicated by small figures in parentheses.

tions in the winter, one team re-studied nine of the mines (selected at random) in December, 1953. No attempt was made to evaluate the effects of any changes in physical characteristics, such as, size and shape of underground workings, composition and structure of ore body, etc. in these mines. It was presumed, however, that any differences would not affect the concentration levels appreciably although, no doubt, they are controlling factors in the production of radon. Table III shows the effect of natural ventilation in winter as compared to summer on radioactivity as measured for radon degradation products and radon.

In all of these mines, with the exception of the mine coded as HN-36, the average concentration for both radon daughters and radon gas was less in the winter than in the summer. The concentrations of the degradation products were reduced by factors varying from 31% to 90%. This reduction can reasonably be attributed to the fact that natural air currents provided better ventilation of the working atmosphere during the winter months. It is important to note that the natural ventilation was not sufficient even in the winter months to bring the radioactive dust concentrations below the presently accepted maximum allowable concentrations.

Air samples taken in the mine coded as HN-36 showed an increase (11%) in radioactive dust in winter as compared to summer. Apparently, the reason for the increase was that this mine was forcing air underground through a churn-drill hole during summer months. In the winter this blower was not operated. Thus, although natural ventilation was greater in winter than in the summer, it was not equal to the summer natural ventilation plus the mechanical ventilation.

From the results of this survey, it can be concluded that under the prevailing operating conditions in the uranium mines of Utah, natural ventilation is a definite aid in reducing concentrations of radon and its degradation products in the working atmosphere, but its effect is neither sufficiently great nor dependable to be relied upon as a control measure. Another report[5] has indicated similar conclusions.

Control Measure Recommendations

SOME MINERS believe the silicosis producing dust concentration in uranium mines should be the criteria for establishing control measures, but this type of dust concentration in uranium mines has usually been within safe limits.[6] However, because of the presence of high concentrations of radon and its short-lived daughters (RaA, RaB, RaC and RaC′) and their greater physiological significance as compared with ordinary hard-rock mining, the ventilation standards should be such that the radioactivity hazard can be controlled. Mechanical ventilation systems plus natural air currents are necessary to reduce contaminant concentrations to within safe limits.

Although each uranium mine will present a special problem because of such factors as grade of ore, size of exposed ore body,

etc., it is believed that the following recommendations will control radioactive dust and radon gas in practically all instances under prevailing operating conditions:

VENTILATION:

1. Mechanical ventilation is necessary. It appears more practical in uranium mines to place the mine under positive pressure. The discharge end of the vent tube or duct should be within 20 to 30 feet of each working face. The vent tube should be constructed of suitable material to prevent damage by impact or abrasion, and be capable of being placed around sharp edges or corners. The tubing as installed should provide unobstructed flow. The minimum size vent recommended is one of 12" diameter. The blower (usually located on the surface level) should be of sufficient capacity to produce the air flow recommended in (2) below. At the time of purchase of ventilating equipment, consideration should be given to the possible necessity of increasing its capacity so that the mine can be adequately ventilated as activities and/or contaminant concentrations are increased.

2. Ventilation rates for control of radioactive dust, as suggested by Holaday and Ayer[7] of the Field Station, U.S. Public Health Service, are: For concentrations up to 10,000 micromicrocuries per liter of air, at least 500 cubic feet of air per minute should be applied to the working face of each drift and 1,000 c.f.m. to larger rooms or stopes. For concentrations above 10,000 micromicrocuries per liter of air, the amount of air supplied to the working face of each drift should be at least 1,000 c.f.m. and 2,000 c.f.m. for each large room or stope.

3. Natural ventilation of uranium mines should be fully utilized, but should not be

APPENDIX I.

SCHEDULE OF INSTRUCTION, 1953

Date & Time	Subject	Instructor*
June 1 (Monday)		
Hours		
0830 to 0930	Introduction to the Uranium Study	Mr. Holaday
0940 to 1040	Nuclear Particles	Mr. Holaday
1040 to 1200	Radiation Units	Mr. Ayer
1300 to 1415	Uranium Decay Series	Mr. Holaday
1430 to 1530	Theory of Instruments	Mr. Ayer
1530 to 1630	Survey Meters—Methods for Calibration of the Juno	Mr. Ayer
June 2 (Tuesday)		
0830 to 0930	Absorption of Radiation & Ionization	Mr. Holaday
0940 to 1040	Collection & Evaluation of Radon & Daughter Products	Mr. Holaday
1050 to 1200	Mine Practices & Terminology	Mr. Pett
1300 to 1630	Calibration of Junos & Pumps: Plotting of Data Practices (Laboratory Exercise)	Staff
June 3 (Wednesday)		
0830 to 0930	Mine Ventilation (Types of Measuring Instruments)	Mr. Morrill
0940 to 1040	Survival on Colorado Plateau Desert	Mr. Pett
1050 to 1200	Collection of Data for the Surveys, Mine Sketches, Etc.	Mr. Morrill
1300 to 1630	Review & Additional Misc. Subjects	Staff
June 4 (Thursday)		
All Day	Field Trip—Survey of Tough Luck Mine	Mr. Morrill
June 5 (Friday)		Mr. Pett
Laboratory:	Preparation of sampling and personal equipment	

*DUNCAN HOLADAY and HOWARD AYER, U.S. Public Health Service Field Station, Salt Lake City, Utah.
E. ELBRIDGE MORRILL, JR., Utah State Department of Health, Salt Lake City, Utah.
VICTOR G. PETT, Chief Inspector, Industrial Commission of Utah, Salt Lake City, Utah.

relied upon entirely to remove the contaminants from the working atmosphere.

4. Mine layouts, including ventilation raises, should be designed so as to establish effective air courses throughout the underground openings. Surface openings should be at a different elevation, if possible, from the main airway inlet to facilitate natural ventilation.

5. It is suggested that the ventilation system be allowed to operate for at least thirty minutes before miners enter the working area, and continuously as long as men are underground.

OTHER RECOMMENDATIONS:

6. Facilities should be provided so that the workers are able to practice good personal hygiene, including daily showers and frequent change of work clothes. Food should be neither eaten nor stored in the mines.

7. Pre-employment and periodic medical examinations should be done on all workers. These examinations should include detailed occupational and medical histories, chest x-rays and laboratory analyses of blood and urine.

Acknowledgment

THE AUTHOR gratefully acknowledges the generous assistance given by the professional staff of the U.S. Public Health Service Field Station, Salt Lake City, Utah, during this entire study and the cooperation of the operators of the mines surveyed.

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6. Utah State Department of Health, unpublished data, 1951.

7. HOLADAY, DUNCAN, and AYER, HOWARD: U.S. Public Health Service Field Station, Salt Lake City, Utah. Personal communication.

Suggestions Invited

INDUSTRIAL HYGIENE AND TOXICOLOGY, the collaborative book, edited by FRANK PATTY and published by Interscience Publishers, is to be revised and enlarged. A new third volume is planned to deal with methods of sampling and analysis in a broad sense, while, as before, some suggestions on detailed analytical methods will be given under the discussion of the individual materials. Volume I, which will be revised first, will have added chapters dealing with atmospheric pollution, air cleaning, illumination, noise, radiant heat, and possibly safety. In the interest of making the book more useful MR. PATTY invites suggestions regarding errors or omissions in the present volumes and especially any additional materials of industrial importance or pending industrial importance that should receive consideration of physiological effects. Any comments, criticisms or suggestions are welcomed and should be directed to: FRANK A. PATTY, Head, Industrial Hygiene Department, Research Laboratories Division, General Motors Corporation, P.O. Box 188, North End Station, Detroit 2, Michigan.

Determination of Sulfur Dioxide in Atmospheric Samples

COMPARISON OF A COLORIMETRIC AND A POLAROGRAPHIC METHOD

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THE DETERMINATION of sulfur dioxide in the atmosphere has been the subject of many investigations. Most often used has been the reaction with iodine and subsequent measurement of the excess iodine by titration with thiosulfate[1] or modifications of this procedure.[2,3,4] A variant of this involves the collection of SO_2 in alkali and titration with iodine.[5] Other methods are based on the reaction of SO_2 and H_2O_2.[6,7] In general, these methods lack the sensitivity required for the low concentrations encountered in studies of atmospheric pollution.

A colorimetric method for sulfur dioxide developed by Steigmann[8] was adapted to the determination of SO_2 in air by Grant[9] and modified by other investigators.[10,11,12] This method uses a basic fuchsin-formaldehyde color reagent which develops a red-violet color in the presence of sulfurous acid. The intensity of the color produced is proportional to the concentration of the SO_2 present and can be measured accurately by means of a spectrophotometer or colorimeter.

A polarographic method, which involves the reduction of sulfurous acid at the dropping mercury electrode, was introduced by Kolthoff and Miller[13] and later modified by others.[14]

Inasmuch as methods for SO_2 determination have such wide applicability, it was considered worthwhile to evaluate the colorimetric method and a recently improved polarographic method in order to reveal possible discrepancies in these methods. Such discrepancies theoretically could arise from the inherent tautomerism of SO_2 in aqueous media. As a result of this study, (1) a comparison of the sensitivity of the two methods for SO_2 has been made, (2) the reproducibility of each determined, and (3) the extent of their agreement shown. As a further step, the stability of SO_2 solutions under a variety of conditions is reported.

Colorimetric Method

PREPARATION OF REAGENTS:

Stock Solution I: 460 ml. distilled water, 44 ml. concentrated sulfuric acid and 16 ml. of a 3% solution of basic fuchsin in ethyl alcohol were placed in a one-liter bottle and shaken vigorously for several minutes, after which 280 ml. distilled water and 4 g. of Norit-A® activated carbon were added and the mixture again shaken for several minutes to insure complete mixing. This solution was refrigerated overnight, after which it was filtered twice through Whatman No. 42 filter paper, or its equivalent, to remove the carbon. The solution was then ready for use, and if refrigerated, could be used for several months. It is important that the proper amount of carbon be added. The resulting filtered solution should be light amber color for proper color development.

Stock Solution II: 5 ml. of 40% formaldehyde were diluted to 100 ml. with distilled water.

Color Reagent: One part of solution II was added to 10 parts of solution I, mixed, shaken, and used after 30 minutes.

Collecting Medium: 2% glycerol in 0.05 N sodium hydroxide (pH 12).

Standard Sulfite Solution: Sodium metabisulfite ($Na_2S_2O_5$) was added to a quantity of collecting medium to give the equivalent of approximately 100 μg SO_2/ml, then the solution was accurately standardized with 0.01 N iodine solution.

Equipment: A Beckman Model DU Spectrophotometer was used with a 20 mm. cell. Readings were made at 570 mμ with a slit width of 0.03 mm. A Klett-Summerson Photoelectric Colorimeter was also used with a 20 mm. cell and a KS56 filter having a range from 540 to 590 mμ.

STANDARDIZATION:

A series of solutions were prepared containing from 1 to 10 μg of SO_2/ml of collecting medium. One milliliter of each of these solutions was placed in a 20 mm. test tube (transmission cell) along with 10 ml. of collecting medium and 5 ml. color reagent. The color was allowed to develop and was read between 10 and 20 minutes after addition of the color reagent. A standard curve was then constructed from the spectrophotometer or colorimeter readings.

ANALYSIS:

The samples were treated in a similar manner to the standards with the exception that from 1 to 11 ml. of the samples, depending upon the concentration of SO_2, were placed in the 20 mm. cells and a sufficient amount of collecting medium added to bring the total volume in each to 11 ml., then 5 ml. color reagent was added, and the color developed and read.

EXPERIMENTAL:

Only analytical reagent grade basic fuchsin was used. Even this material gave solutions varying in color from tan to reddish-brown which tended to give a high blank and reduce the sensitivity of the method by narrowing the range for the readings on the spectrophotometer. Segal[15] likewise found varying shades of colored solutions with different batches of basic fuchsin which interfered with his procedure. To eliminate this interference, he used activated carbon to decolorize the fuchsin-sulfite solution with good results. In our study, Norit-A® activated carbon was used to reduce the color in the fuchsin reagent to light amber. Such a preparation yielded satisfactory results. Reducing the color beyond this point gave erratic results. It was necessary to establish a new standard curve with each new batch of Stock Solution I.

TIME FOR COLOR DEVELOPMENT:

Thirty minutes had been suggested[11,12] for color development by this reaction before reading. Samples containing 0, 1, 2, 5, and 7 μg of SO_2/ml, respectively, were read in the Beckman spectrophotometer every minute for 40 minutes after the color reagent had been added. It was noted that the color in each sample containing SO_2 increased to a maximum and then gradually decreased. The results showed that the optimal time for taking the readings was from 12 to 20 minutes after addition of the indicator. The change in color up to 35 minutes was not appreciable, and any period from 10 to 35 minutes can be used. It was essential that the solutions used to construct the curve and the unknown samples be read within the same time range. It was also found, in agreement with Urone,[1] that room temperatures from 23° C to 26° C did not affect the readings appreciably but that higher temperatures did give increasingly erroneous results.

KLETT VS. BECKMAN:

In air-pollution studies, it is sometimes advantageous to be able to determine the SO_2 content of the samples in the field soon after collection. For this purpose, a portable-type instrument can be used to good advantage. To this end a Klett-Summerson photoelectric colorimeter (using a KS56 green filter) was compared with a Beckman Model DU spectrophotometer (read at 570 mμ). The Klett instrument is portable and can be operated from a 115 volt AC or DC line. Two hundred samples, representing a concentration range from 0.40 to 8.50 μg SO_2/ml were read by both instruments. The results obtained by the Klett instrument averaged 99% of the results obtained by the Beckman instrument with a standard deviation of 2.23.

SENSITIVITY:

The smallest amount of sulfur dioxide that could be accurately measured by the colorimetric method approximated 0.1 μg SO_2/ml sample. Below 0.1 μg/ml the readings approached the blank readings and the results were erratic. The greatest accuracy was obtained in the range from 2 to 10 μg SO_2 per aliquot taken for color development.

REPRODUCIBILITY:

A reproducibility of $\pm 2\%$ variation from

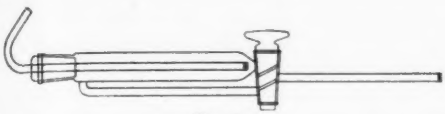

Fig. 1.

the average was found for 12 determinations in the same day for a sample within the optimal range.

It was necessary to dilute samples containing more than 0.9 μg SO_2/ml in order to bring the total SO_2 in an 11 ml. aliquot within the range of the method. Dilutions as great as 1:10 showed little or no loss of precision and reproducibility. At greater dilutions, there was a marked tendency to give inconsistent results when several dilutions of the same sample were determined. The results usually increased with the degree of dilution but were neither consistent nor proportional. Errors in making dilutions were not responsible. It is unusual that greater dilutions than the above are required for outdoor air samples.

Polarographic Method

PREPARATION OF REAGENTS:

Acetate Buffer: 2.5 M acetic acid in 0.5 M sodium acetate. This gives a pH of 3.85-3.95.

Collecting Medium: 2% glycerol in 0.05 N NaOH. (Same as for the colorimetric procedure.)

Standard Sulfite Solution: Sodium metabisulfite in collecting medium. (Same as for the colorimetric procedure.)

Equipment: A Sargent Model XXI Visible Recording Polarograph with special deaeration chamber (Fig. 1). This chamber is so designed that 5 to 20 ml. buffer solution and the equivalent size sample can be separately deaerated by the same stream of nitrogen, then the solutions combined in the electrolysis vessel without exposing either solution to the air. With the buffer solution in the chamber and the lower fritted disc immersed in the sample, nitrogen is bubbled first through the buffer and then, via the by-pass tube, through the sample. After deaeration, a turn of the stopcock drops the buffer solution into the sample without discontinuing the nitrogen stream or admitting oxygen.

STANDARDIZATION:

Each of a series of standard solutions containing from 0 to 10 μg SO_2/ml was run by placing a measured amount of the solution (5 to 20 ml.) in the electrolysis vessel, and an equal amount of acetate buffer in the deareation chamber. Oxygen was removed by bubbling nitrogen through these two solutions in series by means of the deaeration chamber. After the solutions were combined in the electrolysis vessel, stirring was achieved by continuing the flow of nitrogen for 1½ minutes. The flow of nitrogen was then stopped and a polarogram made from −0.35 to −1.00 v. A sensitivity of 0.006 microamperes/mm was used for most of the determinations in this study, but any of the sensitivity settings on the instrument (0.003 to 1.500) could have been used. A standard curve was constructed from the diffusion currents indicated by these polarograms for the several concentrations of SO_2.

ANALYSIS:

Samples were made to suitable volume and treated in the same manner as the standard solutions.

EXPERIMENTAL:

To determine the proper concentrations of NaOH and glycerol for the polarographic collecting medium, various proportions of each were tested. Polarograms were made for each of the solutions over a period of approximately one month. The initial concentration was 100 μg SO_2/ml in each solution. Using 5% glycerol it was found that either 0.05 N NaOH or 0.1 N NaOH gave a diffusion current of about seven microamperes initially and after a month had decreased only 10%, while NaOH concentrations of 0.5 N, 1.0 N, and 2.0 N gave diffusion currents of 5.4 to 5.7 microamperes and those decreased over 50% in one month. Using the same concentration of SO_2, with 0.1 N NaOH, good results were obtained with 1, 5, and 10% glycerol, giving diffusion currents of 7.1, 7.1, and 6.3 microamperes respectively, with a decrease of less than 10% in one month. With no glycerol, the diffusion current was 5.6 microamperes and decreased over 50% in less than a month. In view of these results, 2% glycerol in 0.05 N NaOH was chosen as the standard collecting medium for this study.

The deaeration chamber was designed to use small fritted glass discs for dispersion of the nitrogen into very fine bubbles (Fig. 1), which allowed deaeration to be accom-

plished within five minutes. An optimal time for stirring was determined to produce homogeneity of the buffered solution with a minimal loss of SO_2. With a concentration of 7 μg SO_2/ml a loss of 1% SO_2/min was found for a range from 1 to 20 minutes stirring. Whereas stirring for less than one minute at the same flow rate of nitrogen as used in removing dissolved oxygen was found to be inadequate, a faster rate tended to carry the sample out of the electrolysis vessel. Therefore, an arbitrary time of 1½ minutes was chosen for stirring the samples, timed from the opening of the stopcock of the deaeration chamber for release of the buffer solution into the sample.

SENSITIVITY:

Concentrations as low as 0.5 μg SO_2/ml of sample were determined with an accuracy of ±10%. The standard curve (concentration vs. wave height) was a straight line which passed through the zero point; therefore, lower concentrations could be determined, dependent largely on the ability to measure the inked lines on the polarogram.

REPRODUCIBILITY:

When a single sample of approximately 5 μg SO_2/ml was run repeatedly during the same day, the results differed not more than 2% from the mean. Even better reproducibility was obtained with standards.

Collection of Samples

FOR COMPARISON of the two methods, samples containing SO_2 in concentrations from 0.5 to 12.0 μg/ml were selected as a useful range for both methods, inasmuch as the higher value included the upper portion of the colorimetric method's range and the smaller value, the lower portion of the polarographic method's range. Samples were collected in a Greenburg-Smith all-glass impinger containing 100 ml. of the collecting medium. Each sample was taken from outside air at a rate of 24 liters/min. for 30 minutes. For SO_2 concentrations from 0.5 to 2.0 μg/ml of solution (equivalent to 0.027 to 0.106 ppm by volume in air), the outdoor air was sampled on different days. For greater concentrations (2.0 to 12.0 μg/ml of solution, equivalent to 0.106 to 0.64 ppm by volume in air) SO_2 gas was added to outdoor air which had been drawn into a chamber. After mixing, this was sampled in the same manner.

Urone and Boggs[10] reported sampling with a midget bubbler, containing 10 ml. of 5% glycerol in 0.1 N NaOH, at a flow rate of 20 liters/hr. for a period of one-half hour (usually). At this rate they reported a collecting efficiency of close to 100%. Stang, *et al.*,[12] using a Greenburg-Smith all-glass impinger, containing 100 ml. of 1% glycerol in 0.05 N NaOH, sampled at approximately 20 liters/min. up to 28.3 liters/min. and showed results from 93-99% efficiency based on the amount of SO_2 collected in two impingers in series.

To obtain solutions containing from 0.5 to 12.0 μg SO_2/ml, it was necessary to sample at a more rapid rate than that used by Urone. Experiments conducted in this laboratory gave an average sampling efficiency of 82.1% for the Greenburg-Smith impinger at a rate of 21 liters/min. for 20 experiments having SO_2 concentrations from 0.08 to 0.25 ppm. Accurately measured SO_2 gas (2% SO_2 in N_2) was mixed with room air in a small mixing chamber immediately before sampling. For a blank, the room air was sampled simultaneously at the same rate. With similar experiments, the midget impinger, at a sampling rate of 2.83 liters/min. (0.1 ft^3/min.), gave an average sampling efficiency of 76.4% for 12 samples. Likewise, a fritted plate bubbler at 15 liters/min. gave an efficiency of 77.9% for nine samples.

EFFECT OF AGING:

Analyses were made on 56 samples to determine the loss of sulfur dioxide due to aging of the sample. These analyses were made immediately after sampling, and one, three, and six days after sampling. A summation of the results of 224 determinations made by each method is shown in Table I. In this table the results of the SO_2 determinations on the 1st, 3rd, and 6th day after the samples were taken are presented as the percentages of the original determinations. In general there was only a small loss of SO_2 in the samples. Average losses of 6% by the colorimetric method and 5% by the polarographic method were found in six days. The samples that showed increases during one-, three-, or six-day periods were mostly in the lowest range of concentrations.

EFFECT OF LIGHT:

To determine whether sunlight or arti-

ficial light had any influence on the aging of the samples, 20 samples, after anaylsis, were stored in amber bottles in a dark recess of a drawer. Determinations were made after one, three, and six days. The loss of SO_2 in these samples did not differ from the loss in such samples exposed to light in clear bottles for the same period.

TABLE I.
FREQUENCY DISTRIBUTION OF THE PERCENT RECOVERY OF THE SO_2 IN SAMPLES OVER A PERIOD OF SIX DAYS

Percent SO_2 recovered	Time Elapsed							
	1 day		3 days		6 days		Total	
	P*	C†	P*	C†	P*	C†	P*	C†
71-80	0	0	1	0	2	8	3	8
81-90	3	11	7	9	13	4	23	24
91-100	41	41	36	35	33	34	110	110
101-110	8	4	6	12	6	10	20	26
>110	4	0	6	0	2	0	12	0

*Polarographic method. †Colorimetric method.

EFFECT OF AGITATION:

In an effort to determine whether loss of SO_2 would occur if samples were shipped by mail, 10 samples were placed on a rotary shaker and agitated for 11 hours over a two-day period. There was a slight increase in temperature in the samples from heat from the electric motor of the shaker. Determinations by both methods, before and after this treatment, showed a loss of SO_2 comparable to that of the aging experiments.

Results and Discussion

TABLE II gives a comparison of the results of the analyses of 240 samples by each method. The comparisons are expressed as a ratio of the polarographic result (P) to the colorimetric result (C). It may be seen in Table II that the average P/C values increase as the concentration increases.

The polarographic results consistently averaged from 2% to 7% less than the colorimetric results depending on the concentration range. This is shown in Table III which presents the same data in a frequency distribution. A wide distribution of P/C values is shown in the 0-2 and 2-4 μg/ml ranges and a much narrower distribution in the greater-than-8 μg/ml range. The wide distribution in the P/C values in the lower concentrations might be explained partly by the fact that the values are small and a

TABLE II.
COMPARISON OF COLORIMETRIC AND POLAROGRAPHIC DETERMINATIONS OF SO_2 SAMPLED FROM AIR

Concentration range (μg SO_2/ml)	Number of samples	Average P/C
0-2	41	0.93
2-4	58	0.95
4-6	62	0.95
6-8	46	0.98
>8	33	0.98

TABLE III.
FREQUENCY DISTRIBUTION OF P/C VALUES ACCORDING TO CONCENTRATION RANGES

P/C μg/ml:	0-2	2-4	4-6	6-8	>8	Total
0.71-0.80	8	3	2	2	0	15
0.81-0.90	13	11	15	2	0	41
0.91-1.00	14	27	33	24	24	122
1.01-1.10	4	16	10	17	9	56
>1.10	2	1	2	1	0	6
Total	41	58	62	46	33	240

difference in determination of 0.1 or 0.2 μg/ml would represent a larger percentage difference. Another factor is the normal error to be expected in determinations of this nature which would be magnified in the lower ranges. An explanation for the fact that the P/C values average from 2% to 7% below theoretical is more difficult. Because both standard curves were made from the same standards and the samples were analyzed by both methods at the same time, one would think that the average P/C values would be 1.00 ± 0.01 or 0.02 with values ranging equally on both sides of 1.00. The mechanism of reaction involved in each method might explain why the P/C values do not follow this pattern. According to Kolthoff and Miller[13] only one of the two tautomers of sulfurous acid is reducible at the dropping mercury electrode, and at pH 4 (the pH of the determination) there is less of the reducible tautomer ($(HO)_2S{=}O$) present than the nonreducible tautomer ($HO(H)S({=}O)_2$). The colorimetric determination involves a similar situation in that the reaction of fuchsin with sulfurous acid yields two different compounds, only one of which results in a red color in the presence of formaldehyde.[16] Thus, in each case, only part of the total SO_2 in the sample is de-

termined, and by a different reaction. The same standards were used for both methods but air-borne substances could have been introduced into the samples which might have influenced the results in a manner different from that in the test solutions from which the standard curves were made.

Dissolved oxygen was present in greater amounts in the samples than in the standards. Because the dissolved oxygen is removed in the polarographic method but not in the colorimetric method, a test of the influence of this factor was made by determining the SO_2 content on a portion of a solution from which the oxygen had been removed by a flow of nitrogen. Colorimetric determinations of the SO_2 content failed to show appreciable difference between the original and the oxygen-free solutions. The authors have no experimentally proved explanation at present for the apparent discrepancy between the two methods. Further work on the effect of atmospheric pollutants on the sulfur dioxide determinations may reveal the cause of the discrepancy.

Summary

ATMOSPHERIC samples for sulfur dioxide may be collected in 0.05 N sodium hydroxide solution containing 2% glycerol. The average loss of SO_2 on six days standing was about 6% and the loss is not appreciably hastened by light or agitation.

Polarographic and colorimetric procedures are given for analysis of such samples.

The former is somewhat less sensitive but has a greater useful range. The methods have about equal reproducibility (±2%); but, when compared to each other, consistently lower results (2% to 7%) were obtained by the polarographic method for actual atmospheric samples. Standard solutions prepared from sodium metabisulfite showed good agreement when analyzed by the two methods. It is believed, though not experimentally proved, that the discrepancy between the methods when applied to atmospheric samples is due to tautomerism of sulfurous acid or an unidentified interference.

A portable-type filter photometer suitable for field use was found to compare most favorably with a more expensive laboratory-type spectrophotometer for the colorimetric determination of sulfur dioxide.

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FOG TYPE SCRUBBERS

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THE FOG TYPE scrubber has been discussed to a limited degree in the literature and on two previous occasions at annual AIHA meetings. This paper will extend the previous papers by reporting results of both field and laboratory investigations. Considerable attention will be given to induced air flow and moisture entrainment, some attention to applications, and, except for the work of Kernan with Georgia kaolin clay, only slight attention to efficiencies which have been reported at length in the literature.

Definition

HIGH EFFICIENCY scrubbers which use finely atomized spray, known as fog scrubbers, are being manufactured in this country under several trade names. All of these scrubbers fall into one of two classes depending upon the method of fog generation. In one class, fog is generated by passing the scrubbing medium under high pressure through one or more small orifice nozzles. In the other class, fog is generated by introducing the scrubbing medium under low pressure through jets into a high velocity air stream. The first class includes the Fog Filter, Fogitron, Pease Anthony Scrubber, Scrubjet, and possibly others. The second class includes the venturi scrubber and scrubbers using air aspirated nozzles. Each of the two classes of fog scrubbers can be subdivided as shown:

I. High pressure scrubbing medium
  A. Circumferential spray
    1. Double pass cyclone (Fog Filter)
    2. Single pass cyclone (Fogitron)
  B. Radial spray (Pease Anthony)
  C. Longitudinal spray (Scrubjet)
II. High velocity air
  A. Venturi throat
  B. Compressed air aspirated nozzles

The types of fog scrubbers to be discussed in this paper are those developed by Hudson, i.e., those which employ scrubbing medium under high pressure. Particular attention is paid to the circumferential spray types. The term "fog scrubber" will apply to scrubbers of this type throughout the paper.

Fog scrubbers of the circumferential type are similar to each other in that a number of fog nozzles are arranged in several parallel, horizontal planes to discharge at an angle of 45° with the radius in the direction of air motion. These fog scrubbers differ in one respect, that being the path of air flow. One uses an air flow path similar to the conventional cyclone (Fig. 1). The other, a more recent development, is similar but the air passes only once through the scrubber, although through more than one chamber (Fig. 2).

A longitudinal spray type scrubber, which is the most recent development in fog scrubbers, is shown in Fig. 3.

Principle of Operation

THERE are many factors which will in some way influence performance of a fog type scrubber including chamber diameter, chamber height, air quantity, nozzle pressure, nozzle arrangement, number of nozzles, scrubbing medium, the material to be collected, temperature, nozzle orifice diameter and type of nozzle. A secondary factor is that of entrainment of scrubbing medium. We cannot at this time give a complete evaluation of these factors. We will, however, examine some of these in relation to overall performance.

The present thinking is that impaction, wetting and centrifugal action are perhaps the most important mechanisms involved in dust collection. However, there are

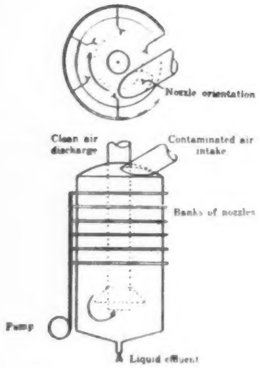

Fig. 1.
Typical fog filter

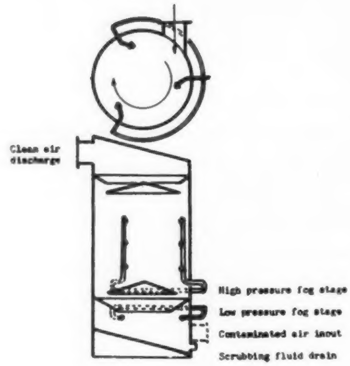

Fig. 2.
Typical fogitron

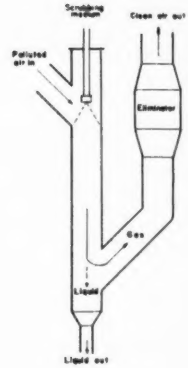

Fig. 3.
Typical scrubjet

not sufficient data to determine the relative importance of each of these factors.

Small particles, say less than ten microns, have little mass associated with them and as a result are difficult to separate from a gas stream by only inertia of the particle. However, if the particle could be made to collide and combine with another particle or with a drop of scrubbing medium, the mass of the new particle might well have enough inertia to be centrifuged from the gas stream.

In order to achieve the maximum impaction rate, it is necessary to produce a very large number of fog particles having a size distribution comparable with the size distribution of the particulate matter to be removed from the gas stream. If the spray drops are large in comparison to the particulate matter, the particles tend to flow around the drop.

The action of the fog scrubber in removing gases and reactive chemicals from the polluted air stream is that of providing a very great surface of scrubbing medium. Thus, we might think of this as being primarily a surface phenomenon although not entirely so.

Applications

THE FOG scrubber has not achieved as much recognition as some air cleaning equipment since there are only two or three manufacturers of this type of equipment, the engineering costs have been high, there is a waste disposal problem in some cases, and as yet there is much to learn about its potentials. However, there are a number of fog scrubbers in operation, and we shall try to point out some of the processes to which they have been applied.

There are three classes of applications for the fog scrubber. They are (1) dust collection, (2) gas and mist scrubbing and (3) odor elimination. Some applications in each of these classes are given in the following paragraphs. Some of the applications cover more than one class: for example, gas scrubbing and odor elimination at an oil refinery.

Successful applications of the fog scrubber have been made to control dust from an asphalt plant, lime fumes from a recalcining furnace, lead oxide from a lead smelting furnace, and iron oxide from an electric furnace.

In the field of chemical scrubbing the fog scrubber has been used to remove H_2S and SO_2 at oil refineries, collect caustic vapors from a parts washer in an automobile plant, collect fumes and dust from an acidulator in a fertilizer plant, and remove free chlorine and silicon tetrachloride released by a reactor tank in a chemical plant.

The fog type scrubber has been used to control odors from oil refineries and lead smelters.

Three applications are particularly interesting. Two are concerned with community air pollution and the other with scrubber liquid effluent.

Krapp and Simonsen reported on fog scrubber installations for eliminating periodic obnoxious odors and occasional irritat-

ing fumes from lubricating oil, grease and asphalt manufacturing processes in an oil refinery in one of our large cities. They found efficiencies of 100% on scrubbing SO_2 and H_2S with scrubber fluid under 400 psi at a flow rate of 23.5 gallons per 1000 cfm. They used a 3% soda ash solution for the SO_2 and 8.5% caustic soda solution for the H_2S. They also report good performance on removal of odors characteristic of their processes.

Field tests on a two-stage fog scrubber used to control odors (particularly H_2S). SO_2 and acid mists released from a process in which animal fats were sulfonated showed efficiencies in excess of 99% on H_2S and over 96% on total sulfur. The first stage employed water at 400 psig while the second stage used a 10% soda ash solution at 30 psig.

Van Dermark noted that water effluent from a 500 psig fog scrubber used to scrub a mixture of free chlorine and silicon tetrachloride from reaction tanks in a chemical plant was supersaturated with chlorine gas to the extent of 15%. Some people believe this to be due to increased absorptivity as a result of the large surface area of the fog particles. Fetz, however, thinks that part of the phenomena is due to hydrolysis of the silicon tetrachloride which forms some HCl. Chlorine is more soluble in HCl than in water, thus accounting for part of the supersaturation.

A longitudinal spray scrubber ("Scrubjet") has been used to scrub acid mists and fumes liberated in filling a storage tank. The unit which was installed on the tank vent, used the rising liquid as the air mover.

Dusts

KERNAN investigated the performance of a fog scrubber of the type shown in Fig. 1 on air of light dust loading in order to evaluate the unit in a region which is normally considered one of low efficiency for many collectors. He studied the effect of only two variables on scrubber performance, (1) air flow and (2) dust loading. He held spray pressure constant at 400 psi and water rate constant at 7.5 gpm.

The unit used by Kernan was small, having a height of four feet and diameter of three feet. Five banks of six nozzles were used in the scrubber. Each nozzle was of the hollow cone type with an orifice diameter of 0.039 inches. A Vickers variable stroke pump was used to supply water to the nozzle. The dust feeder was made with a Syntron vibrator, and only one dust was used in this series of experiments.

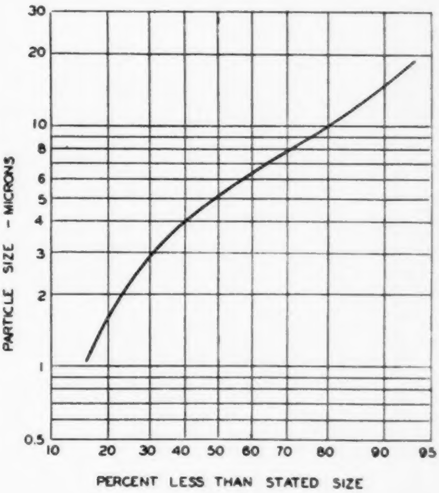

Fig. 4.

The dust used in this test was Georgia kaolin clay. It had a median particle size of five microns as determined by the sedimentation method in the micromeretics laboratory at the Georgia Institute of Technology. The specific gravity was 2.6. Fig. 4 shows the particle size distribution. The reasons for choosing kaolin were its small size and its relative insolubility in water.

The efficiency of the scrubber on a weight basis, expressed as a ratio of dust concentration leaving to dust concentration entering, increased as the dust loading increased. It ranged from 82% for a dust loading of 0.173 grains per ft^3 to about 95% above 1 grain/ft^3. Below a loading of about 1 grain/ft^3 the efficiency falls rather rapidly. Whether it levels off again cannot be answered at this time. The variation in efficiency with dust loading is shown in Fig. 5.

The maximum efficiency of the unit under the conditions in Kernan's test was found to occur at an air flow of 550 cfm. (see Fig. 6). There is reason to believe, however, that for a given contaminant the optimum flow rate will change with spray pressure and

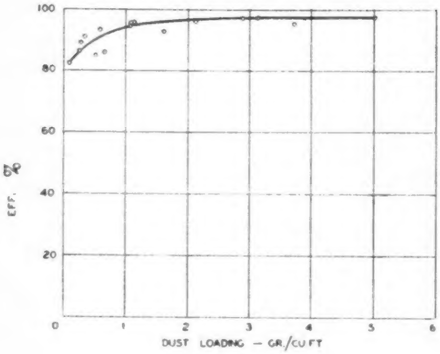

Fig. 5.

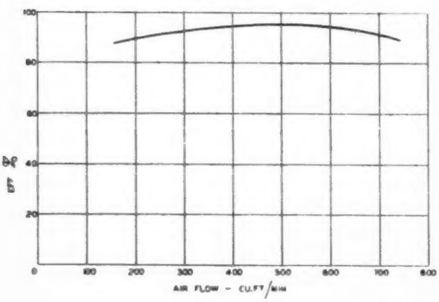

Fig. 6.

number of nozzle banks used. This statement will be partially substantiated later in this paper. Factors of geometry, especially the ratio of height to diameter have not as yet been investigated.

The impinger method of sampling was used by Kernan on both scrubber inlet and discharge. A new technique was used in evaluating the samples. Since a pure dust was fed into the system and the samples were mixtures of only water and Georgia kaolin clay of known size distribution, the spectrophotometric method could be used for determining concentrations of the samples.

Several solutions of known concentration were prepared. These solutions were compared with distilled water in a Beckman type B spectrophotometer. Measurements of optical density were plotted against the respective known concentrations to obtain a calibration curve for the dust used. This curve (Fig. 7) was used to evaluate unknown concentrations of the samples taken.

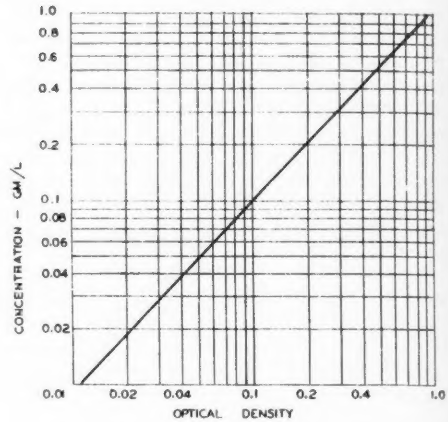

Fig. 7.

The samples were compared with distilled water in the spectrophotometer, and the optical density of each was recorded. The concentrations of the samples in grams per liter were obtained from the calibration curve and then converted into grains per cubic foot.

Physical Aspects of Scrubber Performance

BRIAN modified Kernan's fog scrubber and studied the effect of spray pressure and water flow rate on induced air flow, as well as the effect of spray pressure, water flow rate, and air flow rate on moisture entrainment.

Most fog type scrubbers, because of their construction, will induce quantities of air depending upon both nozzle pressure and quantity of water. Also, air passing through the scrubber reaches a high degree of saturation and in some cases entrains part of the scrubbing medium. If the entrainment is excessive, rainout or precipitation will occur in the discharge line.

Brian found that the quantity of air induced by the action of the spray nozzles was not a linear function of the number of nozzle banks, but an uniform graphical pattern was found. When the nozzle pressure was plotted against a function of air flow and the number of nozzle banks employed, the curves of Fig. 8 were obtained.

Note that for pressures up to about 280 psig all data fall on a common line; then, the effect of four nozzle banks becomes in-

creasingly great until a pressure of about 340 psig is reached. For pressures above 340 psig, the slope of the line is the same as the slope of the line for pressures below 280 psig. This effect is observed again for three nozzle banks at about 450 psig. We can see from this that a mathematical expression for induced air flow in terms of the pressure and water quantity will not be a simple one. It appears that air flow can be expressed as $Q_A = f\ (n^{0.39}e^{P/549})$ where n is number of nozzle banks and P is the pressure. Brian expressed water flow rate as $Q_W = knP^c$ where k and c are constants. Q is expressed in cfm.

The fog scrubber is not likely to eliminate the need for fans except for very limited application; for example, 600 psig water supplied to four nozzle banks at the rate of 18 gallons per minute induced only 216 cfm of air against a static suction of about 0.2 inches of water. From an examination of Fig. 8, we expect higher air flows with more nozzle banks, since additional nozzle banks are likely to cause other shifts in the pumping curve. This means that we will get higher air to water ratios with larger numbers of nozzle banks.

There are possible processes to which fog type scrubbers can be applied without a fan being necessary; for example, scrubbing process gases from reactors where dilution of the gases with air is not desired. This is a likely solution, since flow rates for gas scrubbing range up to about one-half the air flow rates for dust collecting.

Entrainment of scrubbing medium in air leaving any type of wet collector can be, and often is, a disagreeable problem. Many of us have encountered maintenance problems on discharge ducts from some type of scrubber resulting from entrainment of corrosive scrubbing medium. Some of us have encountered secondary air pollution problems in cases where caustic or corrosive scrubbing mediums were used. However, almost any manufacturer of scrubbing equipment will modestly admit that his product is one of the very few which eliminates this entrainment. Under proper condition he is likely to be correct.

Since the air leaving the scrubber was suspected of containing entrained moisture, it was necessary to provide some means for determining the magnitude of the entrainment. Several means were considered among which were chemical absorption, refrigeration and reheating. The method of reheating was selected since it required least equipment and appeared to be more accurate for this test.

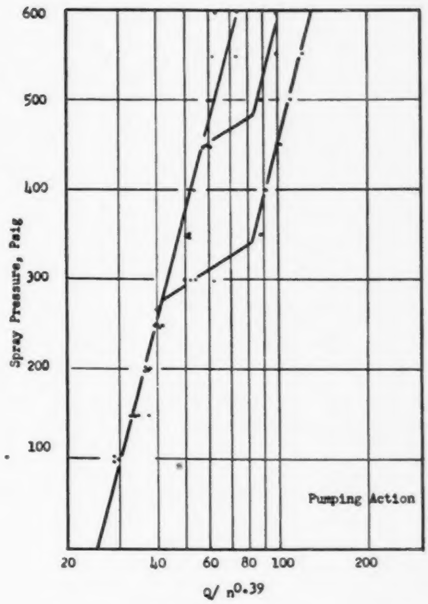

Fig. 8.

Then, too, the wet and dry bulb temperature method is a widely used method of determining the state of air and water vapor mixtures. Errors in temperature vary from 1% to 10% depending on air movement and radiation. Wet bulb methods are acceptable in air conditioning work and were easily adapted to this test.

Brian used the equipment shown in Fig. 9 to study entrainment. His instrumentation centered around wet and dry bulb thermometers placed in various parts of the system. A unit heater supplied with low pressure steam was used to "dry" the air leaving the scrubber. His instrumentation made it easy to obtain large quantities of data relatively fast.

From Brian's data, two factors appear to be particularly important in entrainment, (1) the quantity of air through the scrubber and (2) spray pressure. The number of nozzle banks used is apparently not a sig-

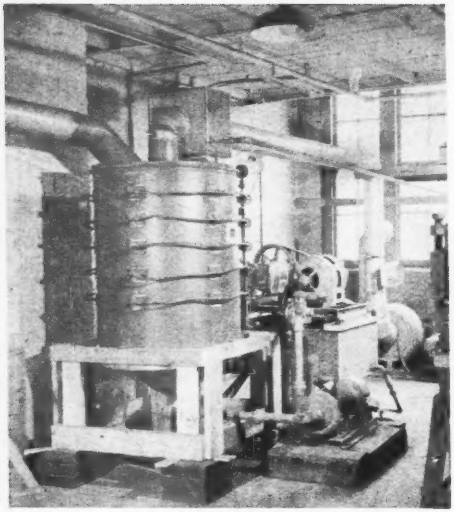

Fig. 9.

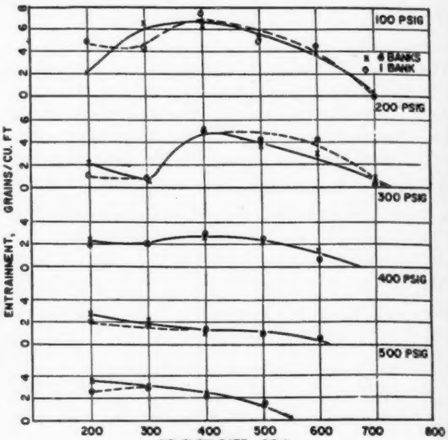

Fig. 10.

nificant factor, although the number of nozzles in a bank may be.

From the entrainment curves in Fig. 10, we see that there is little change in entrainment for air flows up to about 300 cfm regardless of the pressure. However, above 300 cfm for marginal fog pressures (up to 200 psig) there is a marked increase in entrainment which reaches a maximum at about 400 to 450 cfm after which the entrainment decreases to zero at about 720 cfm. Low fog pressures (around 300 psig) produce entrainment characteristics similar to those for marginal fog pressures but produce less than half the maximum entrainment, with no entrainment above 670 cfm. For moderate pressures (400 to 500 psig), there is a continual decrease in entrainment reaching zero at 570 to 625 cfm. For high pressures (over 600 psig) there was no entrainment in the range of air flows from 200 to 800 cfm.

It is interesting to note that as the pressures increased two things happened. First, there was a decrease in maximum entrainment, and, second, the air flow rate at which entrainment disappeared became lower. Further, at low air flow rates entrainment is greater for marginal fog pressures than for low and moderate fog pressures. Although this condition is likely to be reversed for very low air flow rates, this fact is of little practical use since air flow rates are likely to be as high as possible.

Brian defined moisture carryover as the increase in moisture content of the air passing through the scrubber. He found that carryover could be expressed in the form $C=XP^m$ where X and m are both functions of air flow rate.

Based on Kernan's data, the fog scrubber used at the Georgia Institute of Technology has a capacity of about 550 cfm for small dusts when a spray pressure of 400 psi is used. From Brian's curves we would expect an entrainment of about 1.0 grain of scrubbing medium per cubic foot air. However, for gas scrubbing, assuming a capacity of 300 cfm, the entrainment would be of the order of two grains per cubic foot or about two times as high. For lower spray pressures, the entrainment would be worse.

Larger units than the one used by Kernan and Brian are expected to give better performance than indicated here. Reasons include the greater height to diameter ratio (1.5 to 2.1 as compared with 1.3) and the lower water rate (3 to 25 gallons/1000 cfm as compared with 11 to 88 gallons/1000 cfm) used for larger commercial units.

Drop Size

LEWIS, *et al*, expressed fog size as a function involving orifice diameter, nozzle pressure and liquid flow rate in the following form:

$$D=f\left(\frac{Q}{d\sqrt{p}}\right)^{1.5}$$

Since $Q=f\ (d^2)$, the ratio $\frac{Q}{d}$ decreases as *d* decreases and *D* becomes smaller.

Conclusion

THE EFFECTIVENESS of fog type scrubbers is a function of the finely atomized scrubbing medium. These scrubbers may be conveniently classed according to method of generation of the fog.

A rapid method of evaluation of dust samples is explained in conjunction with performance tests of a fog scrubber.

Air induced by the fog is evaluated and an expression of the following form obtained:

$Q=f\ (n^{0.39}e^{P/549})$.

Entrainment of scrubbing medium in the discharge air stream is examined and the following conclusions drawn:

1. Entrainment decreases with increasing pressures and air flow rates for moderate and high fog pressures.
2. Entrainment increases to a maximum and then decreases with increasing air flow rates for low and marginal fog pressures.
3. Entrainment from fog type scrubbers can be reduced or eliminated by using a high pressure scrubbing section prior to discharge of the air.

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Qualifying Exams

THE UNITED STATES Civil Service Commission has announced an examination for Industrial Hygienist for filling positions at field activities of the Navy Department, and in other Federal agencies if the need arises. The salaries range from \$4,205 to \$7,040 a year. To qualify, applicants must have had appropriate education and/or experience. No written test will be given. Further information and application forms may be secured at many post offices throughout the country or from the U. S. Civil Service Commission, Washington 25, D. C. Applications must be filed with the Executive Secretary, Board of U. S. Civil Service Examiners for Scientific and Technical Personnel of the Potomac River Naval Command, Building 37, Naval Research Laboratory, Washington 25, D. C., until further notice.

FILTER MEDIA FOR AIR SAMPLING

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THE SEPARATION of particles from air for the purpose of determining their quantity, composition, size distribution and other properties, has been accomplished by a wide variety of methods embodying several different physical or chemical principles. In its broadest sense the term "filter" may be applied to all of the resultant fractionation devices including sieves, mats, thermal and electrostatic precipitators, scrubbers, impingers, adsorbers, centrifugal separators, and others. Summarization of the essential properties and limitations of all of the useful devices in this broad category would be an encyclopedic task.

The following discussion is limited to those media, for air sampling, which function wholly or in part by mechanical screening. Devices which depend primarily, for their separatory action, on adsorption, reaction, solution, entrainment, electrostatic precipitation, or thermal impingement are not considered. Stated otherwise, the term "filter medium" as used here applies to materials of granular, fibrous, or syncitial (gel) structure, the screening actions of which are at least partially dependent on their presenting a mechanical barrier to the passage of particles suspended in air.

Physical Basis of Filtration

WHILE the arbitrary limitation of scope just stated implies that the removal of particles by "filter media" results from confronting them with orifices through which they cannot pass, in the manner of draining rice or beans, it must be stated that few, if any, media are known in which this is the only separatory mechanism involved. In addition to mechanical screening, at least three other phenomena are usually involved to various degrees in determination of the overall ability of filters to remove aerosols.

1. Relatively thick webs, mats, felts, granular beds and dry gels usually exhibit diffusional separation, especially at low air velocities. This factor is less dominant in thin sheets and is, by and large, not a major factor in those filters otherwise well adapted to sampling for subsequent analysis of the collection.

2. Especially at high air velocities, the inertial characteristics of the air-borne particles themselves become an important factor in filtration through most media. In many types of media the separatory efficiency improves gradually with increase in linear velocity above a well defined minimum. Ramskill's[1] studies of the performance of CWS Type 6 filters illustrate this performance admirably as well as the diffusional separation at low air flow.

3. Complicating the rather reasonable theoretical interpretations of the screening, diffusional, and inertial separation actions is the very real but much less well-understood complex of electrostatic attractions and repulsions accompanying the penetration of a filter by an aerosol. The filter charge and its variations with air flow and humidity, and the charges carried on the several kinds of particles required to be separated are all involved. It seems definitely established that electrostatic phenomena are dominant factors in the efficiency of certain types of filters under suitable conditions, but a satisfactory theoretical analysis of these effects, applicable to practical operating conditions is yet to be formulated. It is evident, from the general nature of the factors involved in removal of particles from air by filtration, *viz.*, sieve size, diffusion, inertia, and electrostatic charge relationships, that the conditions of sampling,

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air velocity, mass, dimensions, and charge of air-borne particles, and related mechanical and aerodynamic properties of the aerosol under study, must be taken into consideration in any explanation of the behavior of a particular filter.

Selection of a Sampling Medium

APPROPRIATE selection of a filter medium for air sampling can probably be approached best through consideration of (a) the use to be made of the collected material, and (b) experimentally derived data relative to the performance of available filter types and their physical properties and compositions.

Often the objective of the analyst is the simple determination of the concentration of material per unit volume of air. When this is the case, primary consideration must be given to the efficiency of the medium in removal of particles above a designated size range, under air flow conditions designed to collect, in a predetermined time, enough material for weighing. There is no need for ability to recover the material from the filter, and no restriction on the chemical content of the medium.

There are more numerous situations in which it is desirable, or necessary, to remove the collection quantitatively, or chemically analyze it *in situ.* In these instances attention must be paid to (a) the ease of separation from the medium, or alternatively (b) the presence in the filter itself, of substances which would interfere with or overwhelm the specific chemical determinations needed. Thus, one would certainly not select a glass filter when analyses are to be made for silicon. Similarly, a filter containing a resin or other organic binder would not profitably be used when analyses for benzene or acetone soluble substances are required.

Still other air sampling operations are designed to provide material for radiological analysis. Normally, in these cases, the analyst will avoid filters allowing deep penetration of particles into the filter substance especially when there is interest in alpha activity.

Often the size distribution of the collected particles is required. Filters are generally not well adapted to collections for this purpose unless they cause deposition of all particles at the surface or can be rendered optically transparent to facilitate direct microscopic observations. Only one of the numerous kinds of filters to be discussed below meets either of these requirements.

The special case of collection for recovery of viable bacteria, and other microorganisms presents unusual problems associated with subsequent recovery from or growth upon the filter.

In many types of investigation, limited sensitivity of the analytical method to be employed imposes air volume requirements which tend to govern selection of appropriate filters. For example, in a typical municipal atmosphere the total weight of particles recoverable by filtration may be of the order of 500 micrograms per cubic meter, with the amounts of specific metallic elements usually representing some very small fraction of this total. Obviously, if the analytical method requires an amount of material in excess of a few micrograms, a considerable volume of air must be filtered. In such cases, prominent factors in filter selection will be the quantity of air which can be handled per unit of time and the efficiency of the filter medium for removal of particles in the desired size range at the requisite flow rate.

The temperature, and the moisture content of the atmosphere under study are sometimes prominent determinants of proper filter media. For example, sampling of stack gases is sometimes facilitated by use of filters capable of withstanding prolonged exposure to heat. Under such circumstances, cellulosic or other combustible substances are useless and choice must be made from the several types of mineral, glass, or other refractory media. When sampling is required under conditions of high humidity, filter media which are relatively nonhygroscopic may be the choice, especially those which do not depend markedly on electrostatic properties for their separatory performance.

Careful analysis of the purposes of collection, probable accuracy of air measurement and analytical procedure, and actual significance of small variations in measured values, will often facilitate choice of filters. The pursuit of fractional differences is often quite unprofitable, and frequently leads to absurd elaboration of methodology. As a simple case, where determination of

total mass of particulates is to be made, extraordinary effort to obtain high collection efficiency respecting very small particles (say below 0.5 μ) is normally unproductive since the mass contribution of this size class is usually neglible in spite of large numbers. Efforts toward approximation of absolute efficiency in such a case encounter serious problems of air flow restriction, and increase the difficulty of sampling with almost no improvement in value of the data obtained.

When the desideratum in air sampling is the provision of a sample of material which can be analyzed for a wide variety of properties, selection of the filter involves the acceptance of compromises to enable reasonable determination of all of the wanted components, with some sacrifice of accuracy respecting any single one. At the present time, there is no type of filter medium available which has proved fully satisfactory for all conditions of sampling and analysis. Probably it is unreasonable to anticipate such a development.

An additional consideration affecting filter selection is the required concentration factor. Substances present in the air to the extent of fractions of a microgram per cubic meter, often require the filtration of huge volumes in order to recover sufficient samples for analysis. Such requirements eliminate media having high resistance to air flow, and those which "plug" rapidly during protracted use. High resistance could obviously be eliminated as a restriction on total volume per unit time by using large filter areas, but the ratio of filter mass to sample mass becomes large and leads to technical difficulties in subsequent analyses.

Types of Filter Media

Almost every porous composition of matter has been employed at one time or another for the filtration of air. A large number of these have proved satisfactory for air cleaning, but the number acceptable for recovery of analytically useful samples is much more limited. The remainder of this paper will be devoted to discussion of some of the types and kinds of commercially available filters that have been employed in studies of particulate components of the atmosphere.

TABLE I.
FILTRATION EFFICIENCIES OF SOME TYPES OF CHEMICAL FILTER PAPERS

Type	DOP penetration at 28 FPM		Dust collection efficiency at 20 FPM
	$\triangle$P (in H_2O)	% Penetration	
Whatman			
# 1	10.6	27.	50
# 4	2.8	73.	15
# 32	38.	0.35	99.1
# 40	15.	8.	85.1
# 41	2.0	75.	26.5
# 41H	2.7	76.	24.
# 42	45.5	0.22	98.8
# 44	40.	0.5	97.
# 50	48.5	0.9	92.
# 540	—	—	67.
Schleicher & Schuell			
# 604	—	—	13.

For convenience of presentation these may be grouped into five general classes respecting composition and structure: cellulosic fibrous papers; inorganic fibrous mats, felts and papers; mixed fiber felts; granular filters; and dry gel or syncitial filters.

1. *Cellulosic fibrous felts (papers):* Many investigators have utilized the easily obtainable and inexpensive papers manufactured for use in analytical chemistry. There are numerous manufacturers of these materials and a host of different types designed for general or special liquid filtrations. Some of them have been found effective in certain air sampling procedures. Exact data on the air screening performance of chemical filter papers are available with respect to only a few of the many kinds. Table I lists some of the pertinent properties of 10 Whatman types and one Schleicher and Schuell type adapted from a report prepared by Smith and Suprenant.[2] These are believed to be generally representative.

The third column of the Table gives the percentage of 0.3 μ dioctyl phthalate smoke (DOP) penetrating the papers at a linear air velocity of 28 feet per minute (FPM) under standard test conditions. Column two indicates the pressure drop ($\triangle$P), in inches of water, at this rate of flow, while the last column shows the efficiencies of the various types for removal of atmospheric dusts at an air flow of 20 FPM. By both procedures the removal efficiencies of Whatman Nos. 32, 42, 44, and 50 are superior. This point of excellence is markedly offset however by the high resistance presented to the passage of air.

As a general rule, the efficiency of these papers is a direct function of pressure loss and stream velocity. For example, it has been shown[2] that Whatman No. 41 exhibits a very high DOP smoke penetration (90%) with a pressure drop of only about one inch of water at an air velocity of 4 FPM, while the penetration amounts to only 2.6% at 200 FPM where $\triangle P = 17.5$ in. of water. It is therefore evident that even the apparently less effective performers listed in Table I may be highly efficient for sampling provided large pressure drops can be tolerated.

The efficiencies of almost all filters improve gradually during collection of a sample. For most chemical filter papers this tendency to "plug" is quite marked and often results in rapid decrease of flow rate. This type of failure is a principal reason why such papers are not employed in high volume samplers.

All of the common chemical filter papers are made of purified cellulose pulp, are low in ash content (less than 0.5 mg. per 9 cm. circle), and of low bulk (less than 0.01 in. thick). Thus, they are well adapted to sampling for inorganic and organic analysis, and for comparative studies of the soiling properties of air constituents. Several workers have employed one or more types for the latter purpose making necessary measurements either by reflectometry or densitometry.

Several types have also been used for collection of samples for radioactivity assays. The tendency of particles to imbed themselves in the pulp matrix results in loss of measurement efficiency with respect to alpha particles (up to 60% as compared to Al foil impingement), but is no serious handicap with respect to beta or gamma activity.[3]

The chemical filter papers are relatively inexpensive, obtainable in an almost unlimited range of sizes, have excellent tensile strength, show little tendency to fray during handling, and are universally obtainable. While their hydrophilic composition presents some technical problems to the analyst, it seems probable that they present more generally useful features for air sampling than any other class of filters.

For the special case of sampling large volumes at high air flows a type of cellulose filter (MSA type S) especially adapted for use on the Staplex high volume sampler is manufactured by Mine Safety Appliances Company and was first described by Silverman and Viles.[4] Concentric fluting permits exposure of about 60 in.^{2} of surface within a total diameter of four inches. This filter has been used in large numbers in the study of air pollution conducted by the Public Health Service in the Detroit-Windsor area.[5] In contrast to the chemical filter papers it is quite bulky (.04 in. thick), it has a high and variable ash content (about 1.3%), and has a DOP efficiency of only 48% at 28 FPM. However, the pressure drop at this flow is low (1.6 inches). It is fabricated with an organic binder which makes it unsuited to analytical work involving organic solvents, and its hygroscopicity makes it difficult to weigh.

As a result of the thickness of the S type filter the influence of diffusional separation in aerosols is apparent at low air flows. The efficiency decreases slightly up to about 25 FM (47%) and then increases steadily reaching a value of about 76% at 200 FPM.

While MSA Type S is still one of the most versatile air sampling filters for high volume work, its properties impose excessive compromises on the analyst. He can obtain comparative data of great value but the analyses made on the collected samples are not much more than approximations.

2. *Inorganic fibrous mats, felts, and papers:* The difficulties inherent in close control of natural organic fiber compositions can be offset to some extent by use of synthetic or natural inorganic fibers. Many types of asbestos filters have been fabricated but none, so far as is known, have been used successfully for air sampling.

On the other hand, filter papers composed of finely spun glass fibers have been employed. At least one commercially available type has been studied as a candidate for high volume sampling. This is a paper manufactured by the Hurlbut Paper Co. and distributed by Mine Safety Appliances Company and designated MSA 1106 B. Thickness of the material is 0.007 to 0.011 inch, weight 63-74 grams per square meter. Manufacturing specifications require a DOP efficiency of at least 99.93% at 28 FM with a $\triangle P$ of 4.4 inches of H_2O or less.[6]

Actual data on collection efficiency of this type of felt, as reported by Smith and Suprenant[2] indicate a remarkable intrusion

of diffusional separation into the performance at air velocities below 65 FPM although the penetration of DOP smoke was no greater than 0.006% under any conditions.

1106-B is fabricated with an organic binder which may account for as much as 7.5% of the total weight. This probably accounts for the off-white color. The tensile strength is at least 3.5 pounds per inch of width but the felt is quite friable and must be handled with care to avoid loss of substance. Within the past year a modification of the 1106-B fiber glass web designated 1106 flash fired fiber glass web, has been cataloged by MSA. A study of the particulate pollutants in the atmosphere over major population centers in the United States and Alaska undertaken by the Robert A. Taft Sanitary Engineering Center required a high volume filter capable of recovering quantitatively the particles from 75,000 to 100,000 cubic feet of air in 24 hours of continuous sampling. Analyses were to be made for total weight, acetone extractable matter, amino-nitrogen, inorganic elements, and beta radioactivity. Foter, Tabor and Lagnese[7] of our laboratories, found that the troublesome organic binder coulud be removed easily from 1106-B fiber glass web, by firing at a critical temperature, with no loss in collection efficiency. MSA has cooperated splendidly in the production of sufficient amounts of the modified form to supply our continuing needs, and have recently stocked the item in 24 inch rolls uncut ($25 per pound). Cut sheets are also available.

The 1106 flash fired fiber glass web exhibits slightly less resistance to air flow than the original 1106-B, but shows slightly improved DOP efficiency (99.97% at 28 FPM). There is some loss of tensile strength during the burning out of the organic binder but the paper can be used in sheets of 63 square inches or more if handled carefully and supported by stainless steel wire screen. It cannot be fluted, hence it is necessary that an adapter be provided for use of flat sheets in connection with the Staplex or other high volume sampler.

Use of the flash fired 1106 has enabled organic analyses by direct extraction from the filter. And, in spite of the glass composition, Cholak and his collaborators at the Kettering Laboratory, have found it possible to perform satisfactory analyses for Mn, Pb, Sn, Cu, Ag, Ti, V, Sr, Be, As, Cr, Mo, Co, Ni, F^-, and SO_4^{--} on the collected samples. Analyses for Fe, Al, Mg, Na, and K are not possible because of the large amounts present in the glass fibers. Additionally, we have been able to analyze the sample for ninhydrin reactive substances and to measure beta and gamma radioactivity without difficulty. The 1106 flash fired fiber glass web is probably the best available high volume sampling medium for all-purpose analysis.

Mine Safety Appliances Company also offers a filter medium built with fibers of a highly refractory substance. Distributed under the trade name "Fiberfrax" this material has properties which should make it useful in sampling very hot stack gases and the like. It may be used in temperatures up to 2900° F. in contrast with the 600° F. limit for fiber glass web. Fiberfrax sheets 0.125 inches in thickness exhibit a DOP smoke collecting efficiency in excess of 99% at 28 FPM with a corresponding pressure drop of only about 3.1 inches of water. So far as is known no experiences with it in air sampling have been reported.

3. *Mixed fiber filters:* A considerable number of filter media containing two or more types of fibers felted together have been developed for air cleaning operations. While some of these have been tried as possible sampling media, their complex composition, thickness and other physical properties have made them unwieldly for such a purpose.

Filters of the mixed type include the well known CWS No. 6 and AEC No. 1 composed of vegetable and asbestos fibers, the AEC glass-asbestos filters, and HV 70 of Hollingsworth and Voss. All these types exhibit high removal efficiency for DOP smoke (greater than 99%) paralleled by relatively small pressure drops (4.2 to 6.9 in. of H_2O) at 28 FPM. All of them show a tendency to decrease in efficiency with increase in air velocity up to 30-40 FPM. At higher air speeds inertial impingement causes the efficiency to increase.

While these papers are appealing in respect to air flow resistance and efficiency it is likely that their usefulness for most air sampling objectives is quite limited.

4. *Granular filters:* A variety of granular materials have been employed in air sampling with reasonable success in a few cases. Many of these, as for example activated carbon, separate by adsorption and are therefore excluded from the present discussion. Another group including granulated sugar, granular gelatin, and other water soluble substances have been used because of the relative ease of recovery of the collected dusts. These substances, when packed in sufficient depth to provide reasonable separation efficiency, offer high resistance to air flow. Indeed, sampling with them is largely restricted to flows low enough to permit diffusional factors to be operative. Most workers have found that the commonly used granular materials are insufficiently purified to permit accurate analysis of the small samples collectable on them.

5. *Dry gels:* On the other hand, at least two general classes of dry gel or syncitial materials have proven sufficiently useful to be placed in commercial production within the past five years.

One of these, developed by Mitchell and his coworkers,[8,9] and manufactured under the name "Gelfoam Bricks, nonsterile" by the Upjohn Company, consists of a dry soluble gelatin foam. It has been used almost exclusively for the recovery of viable microorganisms from the air although there is no apparent reason why it is not usable for other air sampling purposes. The dry foam is obtainable in blocks which may be shaped by means of appropriate jigs. No data on the filtration efficiency or air flow characteristics of this material have been released, although in the hands of the Randolph Field group, it has been found more effective than conventional filters and impingers in the recovery of living bacteria and fungi from the air.

Probably no single type of filter has received as much attention in the recent past as so-called "Membrane Filter." Originally a German development marketed by the Membranfilter-gesellschaft of Goettingen under the name "Membranfilter" this cellulose ester xergel has apparently undergone various modifications and is currently distributed in this country from two sources. The German product is obtainable from Schleicher and Schuell, while a modified version of high uniformity is manufactured by the Lovell Chemical Company under the name "Millipore Filter." Goetz[10,11] has published some of the properties of these filters together with descriptions of their structure. In essence they consist of a thin (0.5 μ) effective sieve layer supported by a spongy dry gel which presents relatively little resistance to air flow. Separation of particles occurs almost exclusively at the topmost surface.

The bulk of the filters is quite small and the ash content is negligible (.0000 g/47 mm disc). They are completely and instantly soluble in simple alcohols and ethers. Retention efficiency for particles above 0.2 micron is extremely high (99.9+%). In fact, the isolation of particles only 0.03 μ in diameter by HA type Millipore filters has been reported.[12]

Two types of Millipore filters are currently offered by the Lovell Chemical Company. One of these designated HA is designed primarily for the filtration of liquids, while the other (AA) is said to be superior for air filtration because of a lesser resistance to flow. Both have been used successfully in air sampling. The pressure drops at 28 FPM are 31 and 24.5 inches of water respectively for types HA and AA, the latter value being about one-half the resistance presented by the best types of cellulosic chemical filter papers.

The measured pore size of the Millipore filters is large in relation to the size of particles actually retained especially in the case of the AA type. Electrostatic forces are believed to play an important role in the action of these dry gels. While no definitive studies appear to be available, it is reasonable to assume that the usefulness of such filters would be impaired by conditions of high moisture.

While these filters are most commonly distributed in the form of 47 mm. discs, either white or black, they may be obtained in larger discs up to 5⅜ inches or in rectangular sheets 22 inches by 48 inches. Disc sizes obtainable are in general adapted to use in special auxiliary equipment providing the necessary mechanical support.

Two features of the so-called "membrane filters" (Lovell or S & S) give them special interest in certain air sampling procedures:

(a) Penetration of tiny particles into the

gel matrix is almost negligible. Thus the collected material is available at the surface for direct microscopic examination by reflection, or by transmitted light after clearing with a drop of liquid of suitable refractive index (immersion oil). Such procedures have proven effective in obtaining size distribution data. Furthermore, the surface deposition permits direct measurement of low energy radioactivity without too substantial absorption losses.

(b) The possibility of rapid solution of the filter after deposition of the sample provides a means of recovery of *all* of the collection in small volume for subsequent chemical and physical analysis.

The cellulose ester gel membranes have been used for air filtration for the recovery of viable microorganisms by a number of investigators. Ability to culture the bacteria and fungi directly on the filter surface after fully quantitative collection has led to substantial improvements in techniques for estimation of the sanitary quality of water. Unfortunately, while the filters will remove bacteria from air, there is evidence that the process of separation kills many of them. Living organisms can be recovered from air more efficiently by other means.

Concluding Considerations

THE FOREGOING brief resumé of some of the indicative properties of common air sampling filter media leads to the conclusion that there is no single material completely compatible with all of the objectives of the analyst. But there usually can be found a filter appropriate to the immediate problem. Probably no single structure can be developed which will meet the technological requirements of all analytical procedures. The very fact that the medium has substance, organic or inorganic, is often restrictive. Variations in separatory performance as functions of air velocity, humidity, length of use, and degree of isoporosity introduce elements of error which are never fully under control. Collection of particulate materials from air by means of filters requires consideration of the purpose of sampling, permissible errors in analysis, the structural and chemical properties of available media, and the nature of the substance being collected. Choice of the filter medium would undoubtedly be facilitated by fuller development of the theory of filtration, especially with respect to electrostatic phenomena but, the hygienist can take comfort from the fact that

Small particles floating in air
Whether ash, or prepared by LaMer,
Can be made to reverse
Their status disperse,
And be trapped by a suitable snare.

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A. M. ZAREM, General Chairman of the National Air Pollution Symposium announces that the Third National Air Pollution Symposium will be held in Pasadena, California, April 18-19, 1955. The Conference is sponsored by Stanford Research Institute in cooperation with: California Institute of Technology, University of California, University of Southern California, Air Pollution Control Association, and Southern California Air Pollution Foundation.

Aerosol Contaminants

MEASUREMENT AND IDENTIFICATION BY MICROSCOPIC AND X-RAY DIFFRACTION TECHNIQUES

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Environmental investigations into the problem of air pollution in the Greater Windsor-Detroit area have been carried on for some years under the terms of an international reference. This paper discusses the results of a project on the examination and identification of inorganic constituents of aerosol contaminants in the Greater Windsor area, by the electron microscope and x-ray powder photographs. The information forms a useful supplement to the knowledge of elements in samples of suspended particulates obtained by spectrographic analyses which have been reported elsewhere. Constituents which have been identified by x-ray diffraction are calcium carbonate, silica, aluminum metal particles, gypsum, ammonium chloride, magnetite, hematite, nickel fluoride, graphite, carbon, brass, solder and cadmium carbonate.

The electron microscope is useful for determining shapes and sizes of particles having diameters below the limit of resolution of the light microscope. Although difficult to use as a tool for identification it nevertheless provides information about the external appearance of sub-micron particles and their tendency to agglomerate. In some cases there is sufficient information available to identify particles by their characteristic appearance. This includes carbon particles, some metallic oxides and bacteria, all of which are shown to be present as atmospheric contaminants in the Detroit River industrial area.

ALMOST every type of industrial activity contributes in some way to the pollution of city air. Some of the major sources are combustion of solid liquid and gaseous fuels, foundry and metallurgical operations, oil refining, chemical operations and paper making. The pollutants may comprise solid material like soot, smoke, fly ash, chemical dusts and metallic fumes, liquid and gaseous compounds both organic and inorganic.

A comprehensive investigation into the nature of environmental contamination of the atmosphere in the Greater Detroit-Windsor area and resultant effects on public health, safety and general welfare of the community has been in progress for several years under the terms of a reference to the International Joint Commission. Some idea of the scope of this investigation and the complexity of contaminants in this industrial atmosphere has been presented by Katz.[1] This paper discusses the methods and techniques employed, and the results obtained, in a project to determine the chemical constitution and physical characteristics of crystalline, inorganic aerosol contaminants and some size and shape properties of other suspended impurities in the Greater Windsor area.

I. LIGHT MICROSCOPE STUDY AND IDENTIFICATION BY X-RAY DIFFRACTION: Numerous methods of analysis have been used on airborne particulates. Perhaps the most comprehensive is that described by Cholak[2] utilizing chemical, polarographic, spectrographic and x-ray diffraction techniques. Elements only are identified by these methods except in the case of the crystalline,

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DR. SHORE is microscopist, International Joint Commission, Ottawa, Canada, and DR. KATZ is Chairman, Canadian Section, Technical Advisory Board on Air Pollution, International Joint Commission.

free silica which is determined by x-ray analysis. In the Los Angeles study[3] an attempt has been made to identify individual particles under the microscope by treating them with reagents and noting their reactions. Combining this information with a knowledge of the optical properties has led to the identification of ammonium sulphate and calcium sulphate ($CaSO_4 \cdot 2H_2O$) in Los Angeles smog. Crozier and Seely[4] also describe a neat method of identifying particles by the haloes produced with specific reagents. In this way they have identified carbonates, chlorides, iron, cobalt and nickel. The application of x-ray diffraction technique to air pollution problems has been mainly in the field of quantitative determination of crystalline, free silica in mine dusts.[5] However, in the present investigation it has proved itself a useful tool in the identification of other airborne contaminants.

The basis of this method of analysis is that each crystalline chemical compound, when powdered and placed in a monochromatic beam of x-rays gives rise to a diffraction pattern which may be registered photographically or with a Geiger counter spectrometer, and which is unique for that compound. In a mixture, each component gives its own characteristic pattern independent of the others, so that the complete pattern of the mixture is the sum of the superposed patterns of the individual components. X-ray diffraction thus provides a powerful method of qualitative analysis, in that it shows not only the elements present but their true state of chemical combination. It has often been pointed out, especially with reference to factory and mine dusts, that the state of chemical combination is of great significance in relation to diseases, e.g., silicosis, while the elementary composition is of lesser importance.

Other advantages of this method are that the physical appearance of the particles being identified may be studied under the microscope, and that, if suitable precautions are taken, positive identification may be made with very small specimens. The photography of specimens having weights of the order of one hundredth of a milligram has been reported.[6] The main limitation of the method is that only crystalline material may be identified.

The major portion of the investigation to date has been carried out on the dust collected on high volume pleated filters. The dust shaken from a filter has the general appearance of a greyish black powder but under the microscope, white particles, various types of black particles, colored particles, fibres, pollen grains and even parts of insects can be clearly seen.

The particles of the material to be identified were powdered and attached with a little duco cement to the tip of a very fine glass fibre in such a way that the specimen projected beyond the fibre, and could be positioned in the beam with the aid of the telescope attachment on the camera. In this way the background fogging caused by scattering from the glass was greatly reduced. The diffraction spectra were recorded on photographic film held in a cylindrical cassette of 3 cms. radius in the Unicam Rotation camera, and copper radiation (λ = 1.54 A) was used for most of the investigation. By measuring the spectra obtained on the film, the spacings of the planes giving rise to these may be calculated. The material may then be identified by referring to the A.S.T.M. index which lists all the compounds on which powder data are available in terms of their three strongest lines. Because of the small size of the specimens available for this investigation, the patterns are not as strong as may be obtained with a standard powder specimen, but in almost every case a definite identification could be made.

Random samples from different filters yielded x-ray powder photographs which indicated the presence of SiO_2 and $CaCO_3$ as the main diffracting constituents. A few other lines were present but these were too weak to be positively identified and it was necessary therefore to separate the various constituents so that those materials present in small amounts and less highly diffracting could be identified.

Various means of separation were used. The first of these consisted of picking out particles of similar appearance as viewed under a low power, stereoscopic microscope (44X).

Some pure white powdery particles isolated in this way were identified as calcium carbonate. There were large quantities of this material present on all the filters examined (Fig. 1).

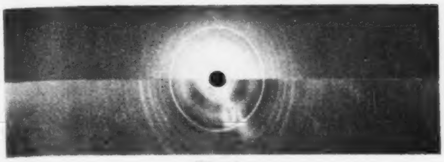

Fig. 1.
(a) White particles from dust, and (b) $CaCO_3$

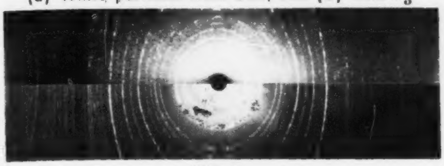

Fig. 2.
(a) Transparent particles from dust, and (b) SiO_2

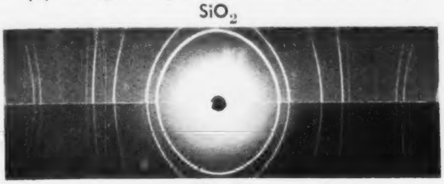

Fig. 3.
(a) Metallic particles from dust, and (b) aluminum

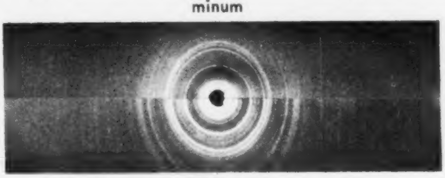

Fig. 4.
(a) Particles recrystallized from water extraction of dust, and (b) $CaSO_4 \cdot 2H_2O$

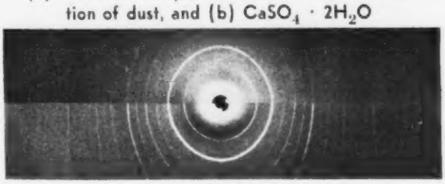

Fig. 5.
(a) Particles recrystallized from water extraction of dust, and (b) NH_4Cl

Fig. 6.
(a) Strongly magnetic particles from dust, and (b) Fe_3O_4

A number of transparent crystalline particles were also separated and shown to be α-quartz. This was by far the most common crystalline contaminant collected on the filters and proved to be quite a nuisance in dry separations as it adhered to other particles (Fig. 2).

Some very small brilliantly shiny particles could be clearly discerned on the filters and these proved to be pure aluminum (Fig. 3).

Since it proved difficult to identify further particles in this way a simple separation by solubility in distilled water was tried. Gypsum and ammonium chloride were identified in the fraction crystallizing from solution (Figs. 4 and 5).

A separation utilizing a magnetized needle point isolated some rather distinctive highly magnetic particles. These comprised small bluish-black shiny spheres ranging in size from 5 to 30 microns (Fig. 7). The powder pattern of these showed them to be magnetite, (Fe_3O_4) (Fig. 6).

Some orange particles which appeared to be less strongly magnetic were also separated in this way. These were very loose aggregates with numerous other particles attached to them. The powder pattern showed good agreement with a standard hematite (Fe_2O_3) photograph. For both these iron oxides, cobalt radiation was used instead of copper to reduce the scattering.

Another portion of magnetic material consisted of dull black plates and proved to be a mixture of hematite, magnetite, and stannic oxide.

The fourth means of separation used was

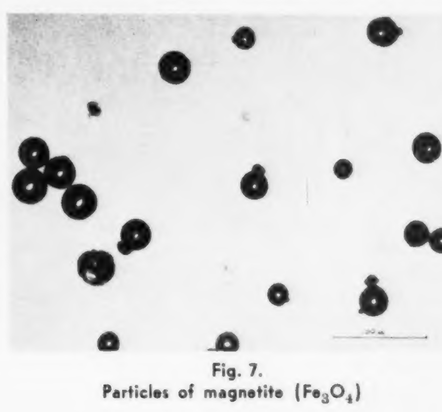

Fig. 7.
Particles of magnetite (Fe_3O_4)

by sedimentation. Dust from a filter was stirred into a gelatine solution and allowed to settle for a short time. When the solution had solidified, it was cut into several sections for examination under the microscope. The heaviest portion, which comprised the particles deposited on the bottom of the test tube, was further separated by panning with distilled water. In this way all but the very large carbon particles were removed and the dust remaining was brightly colored, like sea sand. The average size was about 30 microns so that the task of picking out particles under the microscope was greatly facilitated.

From this fraction nickel fluoride, graphite (Fig. 8) and carbon were identified. Some black coal-like particles which were very widely distributed in the samples proved to be amorphous and could not be identified.

A number of cascade impactor samples were also examined. Being collected directly on glass slides, these are ideal for specimen selection under the microscope, the only disadvantage being that the actual amount of material collected is rather small. Some metallic particles were picked out and identified as yellow brass, and solder (50Pb, 50Sn) (Figs. 9 and 10). A number of transparent, blue tinged, plates were shown to be cadmium carbonate (Fig. 11).

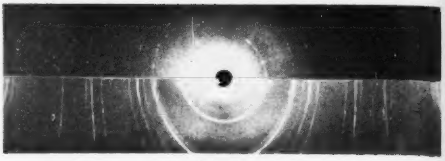

Fig. 8.
(a) Black flakes from dust, and (b) graphite.

Fig. 9.
(a) Metallic particles from dust, and (b) brass.

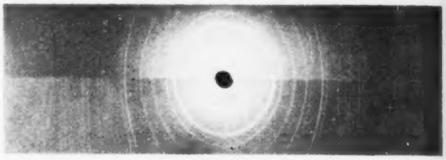

Fig. 10.
(a) Metallic particles from dust, and (b) solder

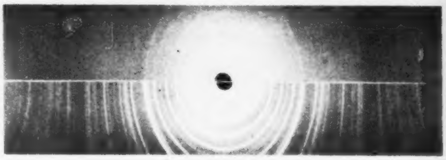

Fig. 11.
(a) Transparent plates from dust, and (b) $CdCO_3$

II. COMPARISON OF RESULTS FROM X-RAY DIFFRACTION AND SPECTROGRAPHIC ANALYSIS: The x-ray diffraction qualitative analysis shows a fair measure of agreement with the quantitative spectrographic analysis of 23 samples of particulate matter collected at filtration stations in the Windsor area.[1]

The diffraction photographs indicated that α-quartz was present in great abundance and this is borne out by the spectrographic results, which show silicon present in the greatest concentration (mean = 6.21 μ gms/cu.m.).

The second most abundant element determined spectrographically was calcium with a mean concentration of 3.26 μ gms/cu.m. This is probably accounted for by the calcium sulphate and to a greater extent by the calcium carbonate detected by x-ray diffraction.

Aluminum was shown to be an important constituent spectrographically with a mean concentration of 2.75 μ gms/cu.m. This will be present not only in the form of metallic aluminum, as identified by x-ray diffraction, but may also exist in compounds which have not as yet been isolated and identified.

The other main constituent in the spectrographic analysis is iron with a mean concentration of 2.49 μ gms/cu.m., and this may be accounted for by the Fe_3O_4 and Fe_2O_3 identified in the present investigation. No metallic iron appears to be present in these samples.

The remaining elements identified spectrographically are in much lower concentrations, all having means of less than 1 μ gm/cu.m. Compounds containing about half of these elements have been identified in the x-ray investigation.

III. EXAMINATION OF SUB-MICRON DUSTS BY THE ELECTRON MICROSCOPE: The electron microscope has been widely used in the study of mine dusts and specific aerosols of industrial origin.[7,8] It has also proved to be an invaluable tool in investigating the efficiency of collection devices using artificially produced aerosols. In the study of general atmospheric contaminants,[3] however, its usefulness has been limited by the difficulty of identifying particles by their external morphology, which is all that this instrument reveals. It does, nevertheless, provide valuable information on the size and shape of particles of 1 μ diameter or less, which are beyond the range of the optical microscope, and often some estimate of the relative abundance and state of aggregation of various particles can be obtained.

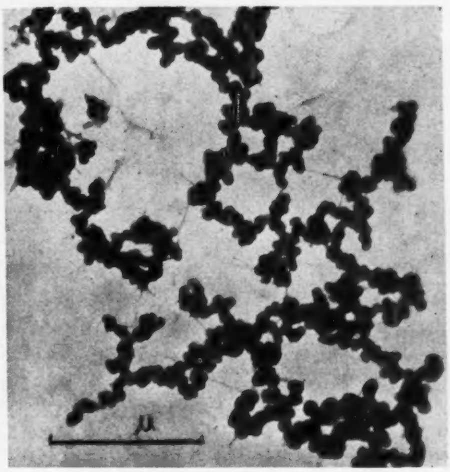

Fig. 12.
Carbon filament of average particle size.

For such a study, the particles should be collected with as little alteration as possible from the state in which they exist in the atmosphere. Membrane filters provide an excellent means of doing this, as the particles are collected on the surface without agglomeration and the efficiency is high for particles of less than 1 μ diameter.

The dust was transferred to electron microscope screens by a method suggested by Kalmus.[9] This consists of cutting a piece of filter smaller than the screen and placing this, dust-side down, on a formvar coated microscope screen. The filter material is then completely dissolved in acetone so that only the deposit is left on the formvar. To dissolve the filter without disturbing the deposit a simple piece of apparatus was used, comprising a bridge of No. 100 wire mesh bent into a U shape and made to fit the inside diameter of a 6 cm. petri dish. A strip of ordinary filter paper was drawn over this and the screens were placed on top. The filter paper was wetted at the

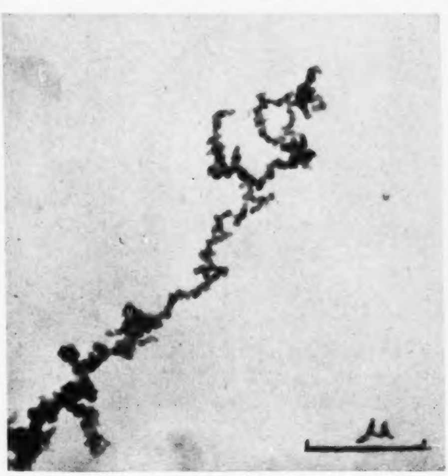

Fig. 13.
Carbon filament of small particle size.

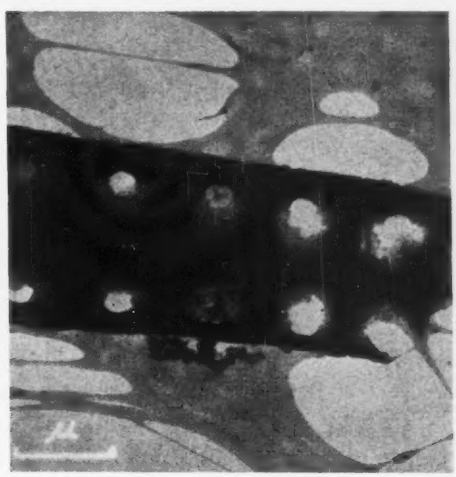

Fig. 14.
Diatom

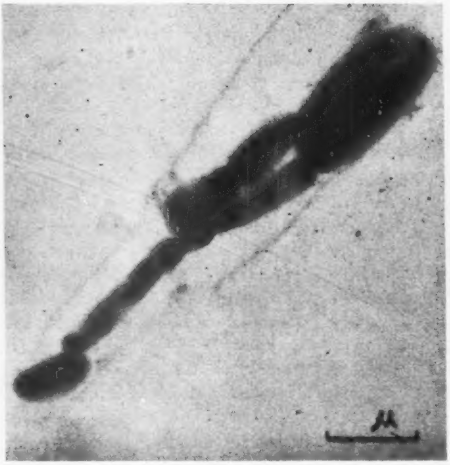

Fig. 15.
Bacteria

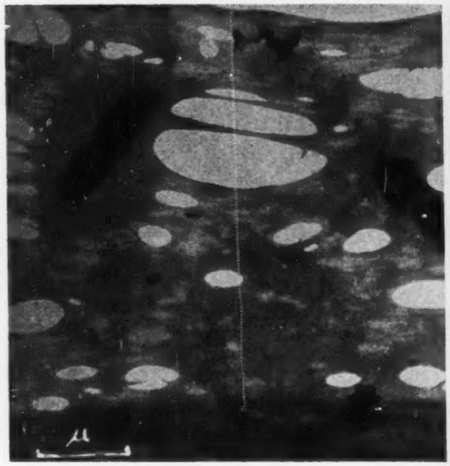

Fig. 16.
Bacteria

edges with a few drops of acetone and the petri dish filled with acetone to a depth of almost half the bridge height. In this way the filter membrane was bathed in an atmosphere of acetone without actually coming in contact with the solvent. After seven or eight hours, during which the acetone was changed every hour, the filter had completely dissolved leaving the dust deposited on the formvar screen ready for study in the electron microscope. By this method the dust was not disturbed at all during transfer to the screen and was in the same state of aggregation as it had been in the air.

A number of samples were collected on millipore filters (Type AA, Lovell Chemical Company) during haze or smog periods in Windsor by sampling air volumes in the range of 2 to 12 litres. The most widely distributed constituent was carbon in the rather distinctive filaments shown in Fig.

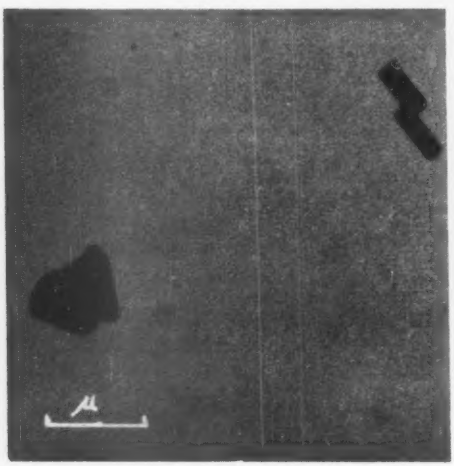

Fig. 17.
Crystalline particles

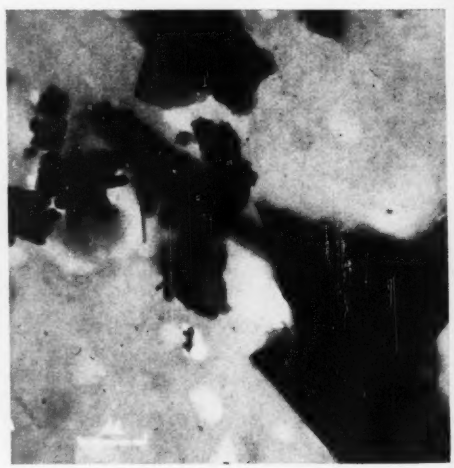

Fig. 18.
Crystalline particles

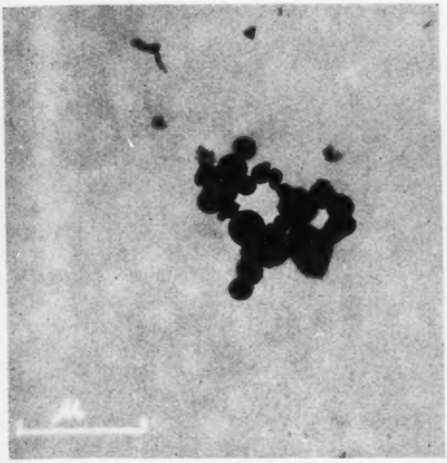

Fig. 19.
Metallic fume

12. The filaments were all quite similar but did show a difference in particle size ranging from 500 to 2,000 A (Fig. 13). Other particles which were recognized by their distinctive appearance comprised a diatom (Fig. 14) and bacteria (Figs. 15 and 16). A number of apparently crystalline particles were found but these could not be definitely identified (Figs. 17 and 18). The spherical particles shown in Fig. 19 appear to be metallic fume and closely resemble fumes collected from the stack effluent of an electric furnace making steels.[8] However other metallic smokes also have this particle shape[10] and a definite identification cannot be made on such factors alone.

Acknowledgement

THE AUTHORS wish to acknowledge with thanks the valuable assistance of L. G. WILSON of Defense Research Chemical Laboratories, Ottawa, in the x-ray diffraction study, and the courtesy of DR. W. H. BARNES of the Physics Division of the National Research Council, Ottawa, in making the electron microscope available.

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Hygienists Needed

THE AIR FORCE MEDICAL SERVICE has a requirement for a limited number of male Sanitary and Industrial Hygiene Engineers to serve on active duty for a minimum period of three years. Recent graduates in Sanitary, Civil, Mechanical, and Chemical Engineering or closely allied branches of engineering with 18 months experience are eligible for direct commissions in the Medical Service Corps in the grade of second lieutenant. Appointments in a higher grade may be made in the case of highly qualified men of proven ability. Professional experience acceptable to state boards of engineering examiners is acquired while on active duty. Applicants should write to: The Surgeon General, Headquarters United States Air Force, Washington 25, D. C., ATTN: AFCSG 25.1. Individuals writing for application forms and information should forward a brief description of their educational background and experience qualifications to include dates of graduation, prior military experience, age, and approximate date of availability for active duty.

✦ President's Page

WEBSTER defines association as: "A union of persons in a society for some common purpose." This definition does not imply any measure of the degree of cooperation or effort in accomplishing the "common purpose." There are those, however, who believe that there has not been sufficient cooperative effort toward promotion of the welfare of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION. For example, the QUARTERLY was given only token support for almost 10 years and had it not been for the painstaking efforts of WARREN COOK, it is more than likely that the magazine would have died a gradual but certain death. He provided the leadership against considerable odds to bid for papers among AIHA members who preferred to publish in "reputable" magazines. He also labored to secure advertising to provide the financial means for continued publication. While the QUARTERLY has made great strides toward overcoming these obstacles, we are still plagued with the same attitudes of indifference in many quarters.

Many members look on the QUARTERLY as a non-technical magazine and a place for publishing general articles which are not acceptable to "established" periodicals. This leads to a situation where basic research in the industrial hygiene field is distributed in a variety of journals and in many cases, almost completely lost to a large percentage of our members. I have discussed this problem with several of our members, particularly those in the industrial toxicological field, who are inclined to publish anywhere except in the QUARTERLY. They usually say "look at it from the standpoint of the author, or the industry or organization for which he works. He is interested in publishing in the periodical having the greatest circulation and the best reputation." My reply has been that publication outside of the QUARTERLY does not necessarily assure the largest reader group. Other periodicals have, at least in part, developed their reputations because of the papers published by our members. No journal begins with a reputation—it is developed.

The QUARTERLY can develop an even better reputation than other competing journals if given the support it deserves. In addition, the results of much research, so important to all our members, could be brought into one journal which would help mold a stronger association serving all its members. If we are really working toward common goals in our Association, there should be no hesitancy to publish the results of all important industrial hygiene research in the QUARTERLY. This should include contributions from all our specialty fields: air pollution, industrial hygiene chemistry, engineering, noise, radiation, and industrial toxicology.

There is still another factor in the problem of industrial hygiene technical paper publication. This is the policy of certain foundations and other organizations to publish papers by their staffs in their own pamphlets as brochures. It is believed that such a practice will work to the disadvantage of such groups over the long pull. These organizations may receive immediate publicity, but in time the data published disappears, for all practical purposes, as a source of reference material. Not only is this unfair to the younger members of the AIHA, but it is damaging to the profession. Publication of such material in the QUARTERLY would have the effect of strengthening the industrial hygiene profession. Also, it would provide for recognition of the author as well as the organization. Would it not be better to publish first in the QUARTERLY where the research would become a permanent part of the scientific literature, and then follow up with booklets or brochures for special distribution?

—HERBERT T. WALWORTH

♦ Selected Titles and Abstracts

—FROM FOREIGN EXCHANGE JOURNALS

THE FOLLOWING is a partial list of articles, by titles and authors, from journals received by the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION since the September, 1954 issue of the QUARTERLY in exchange for copies of the QUARTERLY. Additional information on any of the journals or articles may be obtained from: CARROL S. WEIL, Senior Industrial Fellow, Mellon Institute of Industrial Research, 4400 Fifth Avenue, Pittsburgh 13.

I. LA MEDICINA DEL LAVORO (Italy). Vol. 45, No. 8-9 (1954).

Problems Concerning the Alimentation of Workers Exposed to the Action of Industrial Poisons. E. C. Vigliani, pp. 423 to 430.

The problem of the most suitable diets for workers exposed to lead, benzol, aromatic amines, chlorinated aliphatic hydrocarbons, TNT, CO, penicillin production, and methanol is discussed. It is stated, however, that no food can replace technical prevention of exposure of workers.

Occupational Poisoning from Acetone: Clinical Disturbances, Investigations in Work Rooms and Physiological Researches. L. Parmeggiani and C. Sassi, pp. 431 to 468.

The first part of the paper lists the results of investigations in three plants where acetone is employed (a) as a solvent for polyvinyl chloride yarns, (b) as a lacquering agent for bottles and (c) in the preparation of the colloid and in the acetate rayon pre-spinning. The atmospheric concentrations in (a) varied from 0.029 to 0.205 mg./l., in (b) from 0.200 to 0.350 mg./l., and in (c) from 1/40 to the amount of the maximum tolerable concentration of 1000 ppm. The clinical and laboratory investigations carried out on operators at work have shown the great incidence of chronic disturbances caused by acetone concentrations lower than the MAC: chronic conjunctivitis and pharyngitis, catarrhal bronchitis, gastritis, and gastroduodenitis. Acute intoxication, simple narcosis with irritation of the mucosa, was seen in five workers.

The second part of the paper reports the physiological investigations carried out during work and on subjects in the laboratory to study the elimination, absorption and behavior of acetone in the body in conditions comparable to those of occupational exposure. One-fourth of the amount eliminated in the expired air is eliminated through the skin. Significant absorption through intact skin was shown by suitable experimental equipment.

The third part of the paper reports the deductions concerning industrial medicine. It is suggested to return the maximum tolerable concentration to 500 ppm. Suggestions are given for the prevention and treatment of acetone poisoning.

A Case of Severe Occupational Poisoning from Parathion with Nephritic Syndrome. M. Barsotti, C. Sassi and P. Del Bono, pp. 469 to 473.

Study of the Incidence of Hypertension Among Workers Affected with Lead Poisoning Who Had Previously Suffered from Lead Colic. A. Mazzoleni, pp. 482 to 487.

II. ARHIV ZA HIGIJENU RADA (Yugoslavia). Vol. 5, No. 2 (1954).

Influence of Vitamin C on Working Efficiency in Hot Environment. D. Stankovic, D. Ramadanovic and T. Plecaseva, pp. 185 to 192.

The low content of Vitamin C in groups of workers in hot environments and those performing heavy work in normal thermal conditions showed these subjects almost on the verge of avitaminosis. The administration of C is, therefore, recommended in such cases.

Cadmium Poisoning. Donald Hunter, pp. 221 to 224.

An investigation to determine the incidence of chronic cadmium poisoning in men employed casting an alloy of copper-cadmium has been carried out. Among 63 men exposed to cadmium fume, 16 had symptoms that could have been caused by cadmium. There were eight cases of emphysema and proteinuria, six cases of only emphysema and two cases of proteinuria without emphysema.

The Purpose and Method of Determining the Dust Content of the Air in Factories. F. Hartogensis, pp. 248 to 258.

A wide range of experience has been obtained in Holland in dust determinations in factories to get an idea of the risk of certain diseases, e.g., silicosis, lead poisoning and asbestosis. The methods chosen for these determinations are described in detail, especially the use of the thermal precipitator for determining the number and sizes of dust particles. The correlation between the dust content and the occurrence of silicosis is discussed. The influence of the counting method used on the number of particles obtained is mentioned.

III. THE JOURNAL OF SCIENCE OF LABOUR (Japan). Vol. 30, No. 1 (1954).

Experimental Studies on Phosphatase of Blood Cells Under Chronic Carbon Monoxide Poisoning. Yagasaki Kaoru, pp. 13 to 17.

On the Occupational Boil of Lignite Miners. Mizutani Hisayasu, pp. 25 to 31.

A Medical Survey on Painters: Analytical Studies on Factors for Benzene Intoxication According to Blood Findings. Yamaga Shinro and Saruta Katsumi, pp. 44 to 47.

IV. THE JOURNAL OF SCIENCE OF LABOUR (Japan). Vol. 30, No. 2 (1954).

Studies on the Macrophages Reacting on the Silicious Dust. Yuichi Sata, pp. 69 to 76.

Studies on Phosphatases in Several Industrial Poisonings: On the Serum Alkaline Phosphatase in Lead-Workers. Shinro Yamaga, pp. 77 to 82.

Studies on the Dust Respirator—On the Air Flow Resistance of Filters. Yahatiro Matusita, pp. 83 to 87.

V. THE JOURNAL OF SCIENCE OF LABOUR (Japan). Vol. 30, No. 3 (1954).

On Rest for Working in Hot Atmospheric Condition. Toyohiko Miura, pp. 117 to 124.

Experiments are described on the effect of one hour physical exercise followed by 30, 45 or 60 minutes of rest under conditions varying from dry bulb 35-50° C., wet bulb 30-38° C.

Metachromasia of Toluidine Blue Induced by Silica and Other Inorganic Dusts. Tetsuo Ohi, pp. 136 to 141.

Experimental Studies on the Prevention of Lead Poisoning. Shigeyuki Ohta, pp. 142 to 167.

The influences were studied of administration of calcium, potassium and sodium citrates to rats and rabbits with acute, subacute and chronic lead poisonings.

A Survey on Industrial Lead Poisoning. Report II. Shinro Yamaga and Katsumi Saruta, pp. 178 to 182.

Some Considerations of the Jet Dust Counter. Kikuji Kimura and Tei Taguti, pp. 183 to 187.

VI. THE JOURNAL OF SCIENCE OF LABOUR (Japan). Vol. 30, No. 5 (1954).

Chloronitrobenzene Poisoning. Shigetaka Kubota, Sigeru Nomura and Sumiko Ishizu, pp. 283 to 301.

Studies were reported on dermatitis among CNB workers, diagnosis of CNB poisoning and toxicity of the o-, m-, and p-CNB isomers.

On the Pneumoconiosis Among Workers in a Hard Cutting Tool Factory. Tetsuo Ohi, pp. 317 to 324.

Pneumoconiosis in a Steatite Porcelain Insulator Factory and Experimental Tissue Reaction by Dusts of those Materials. Dengoro Senuma, pp. 325 to 331.

AEC Fellowships

APPLICATIONS for Atomic Energy Commission Fellowships in Industrial Hygiene for 1955-56 are now being accepted by the Oak Ridge Institute of Nuclear Studies. These Fellowships lead to a Master of Science degree in Industrial Hygiene. Training will be received at Harvard University or the University of Pittsburgh, according to the applicants' choice, whenever possible. Fellows must have a bachelor's degree with a major in physics, chemistry, or engineering, and must be acceptable for graduate work at the university to which they are assigned. Fellows must be under 35 years of age and must be citizens of the United States. They must also be granted full security clearance by the Atomic Energy Commission before stipend payments will be made. The basic stipend for the academic year of 10 months is $1600. An additional $350 is allowed for a spouse and $350 for each dependent child. Normal tuition and fees required by the university are paid by the fellowship. Fellows having one or more years graduate work or industrial experience in a related field may be eligible for an additional $200 in the basic stipend. Funds for these fellowships are provided by the United States Government and only the Veterans Administration can advise whether veterans benefits can be received concurrently with these fellowships. Fellows are expected to devote all their time to study and research and may not engage in work for remuneration or receive aid from another scholarship, fellowship, or similar grant during the term of this fellowship. Completed applications, supporting letters of reference and transcripts must reach the Oak Ridge Institute of Nuclear Studies not later than March 1, 1955, to insure consideration. Forms may be obtained from the Fellowship Office, Oak Ridge Institute of Nuclear Studies, Post Office Box 117, Oak Ridge, Tennessee. Appointments will be made on or about March 15, 1955.

News of the Local Sections

Michigan Section

THE MICHIGAN Section held its first meeting of the season October 26. At the invitation of DR. TOD MALLERY, Director of the Institute of Industrial Health at the University of Michigan, the Section met at the Kresge Research Building. The group was taken on a tour to inspect the facilities for research in industrial medicine and industrial hygiene.

A dinner meeting was held in the evening at the Barton Hall Country Club. ARDATH H. EMMONS, Associate radiological Health Officer, University of Michigan, discussed the control of radioisotope exposure, millicurie to kilocurie.

Southern California Section

THE SOUTHERN CALIFORNIA Section met in Los Angeles October 14. C. R. STOWELL, Safety Supervisor, Gladding, McBean and Company was the principal speaker. His subject was "Role of Industrial Hygiene and Safety in the Ceramic Industry." The subject of the November 18 meeting was "Physiological Effects of Excessive Heat Exposures." The speaker was DR. CRAIG L. TAYLOR, Department of Engineering, University of California.

Chicago Section

THE MEETING place of the Chicago Section is now the Western Society of Engineers Building, 84 E. Randolph Street, Chicago. Dinner meetings are held the fourth Wednesday each month. The first meeting of the season was September 22. L. W. WRIGHT presented a film entitled "Ultrasonics in Medical Use." PROF. WARREN A. COOK, University of Michigan, was the speaker at the October 27 meeting. He spoke on "Present Trends in Industrial Solvent Use." The November 24 meeting had as its speaker RAYMOND E. WOZNIAK, Chicago Lighting Institute. MR. WOZNIAK gave a paper on "Office and Industrial Lighting."

Northern California Section

THE REGULAR meeting of the Northern California Section was held in San Francisco on November 9. DR. JOHN DUNNE, U.S. Public Health Service, spoke on the subject "Relation of Occupation to Cancer."

New England Section

AN ALL-DAY meeting of the New England Section was held at the River Works of the General Electric Company in West Lynn, Massachusetts November 3. The following program was presented: "Modern Trends in Industrial Lighting"—LARRY COOKE, District Engineer, Lamp Division, General Electric Company, Boston; "An Iodometric Micro-Method for the Determination of Ozone in Air"—JOHN B. SKINNER, Industrial Hygienist, American Mutual Liability Insurance Company, Boston; "Massachusetts Air Pollution Control Legislation"—EDWARD C. HICKEY, Assistant Sanitary Engineer, Division of Sanitary Engineering, Massachusetts Department of Public Health; "A Condensation Nuclei Meter"—T. A. RICH, Engineer, General Engineering Laboratory, General Electric Company, Schenectady; "A Mounting Technique for Millipore Filters for Optical Microscope Work"—FRED J. VILES, Industrial Hygiene Engineer, Massachusetts Institute of Technology, Cambridge; "Reduction in Incidence of Silicosis After Seventeen Years of Dust Control in the Barre, Vermont Granite Industry"—HARRY B. ASHE, Director, Industrial Hygiene Division, Vermont Department of Health, Barre; "Industrial Hygiene Services in the Aircraft Nuclear Propulsion Department"—JAMES A. MARTIN, Industrial Hygiene Supervisor, Aircraft Nuclear Propulsion Department, General Electric Company, Cincinnati. Following the papers there was a tour of the Measurements Laboratory of the General Electric Company.

Obituary

DR. HENRY FIELD SMYTH, SR., physician and internationally known pioneer in industrial hygiene research died October 15 in Barnstable County Hospital, Pocasset, Massachusetts at the age of 78. DR. SMYTH had lived in Pocasset since 1941, when he became emeritus professor of industrial medicine at the University of Pennsylvania after serving on the faculty for 27 years. While he was a member of the U.S. Public Health Service reserve and other investigative groups, he made an intensive study of anthrax in the tanning industry, tobacco dust in cigar factories and poisonous fumes in the paint manufacturing field. The outcome of his research, including recommendations for corrective measures, was credited with not only improving the working conditions of thousands of workers, but also with saving the lives of many.

✦ In the News

GEORGE D. CLAYTON has announced the opening of his consulting practice in air pollution and industrial hygiene, with offices located at 14125 Prevost, Detroit 27, Michigan.

MR. CLAYTON has had a 12 years' association with the U.S. Public Health Service. During five of these years he served as Chief of the Air Pollution Unit of the Division of Occupational Health. He also served for five years as Chairman of the Technical Advisory Board on Air Pollution of the International Joint Commission.

Specific studies which he has made in the field of air pollution include the Donora field investigation, and a study of the Poza Rica disaster. The Poza Rica, Mexico, Air Pollution study was made at the request of the Mexican government following the death of 20 people and the hospitalization of 320 others.

In addition to his services regarding air pollution problems, MR. CLAYTON is well qualified in the fields of lighting and noise, having specialized in those fields for a period of time in the course of his employment with the Public Health Service.

THE ARTICLE, "Teamwork Will Beat Dermatitis, the Sneaking Intruder," by DR. CLIFFORD H. KALB of Milwaukee, appeared in a recent issue of the *Australian Journal of Industrial Safety and Hygiene*, Melbourne, Australia.

International Air Pollution Meeting

THE HIGHLIGHT of the First International Congress on Air Pollution to be held at the Hotel Statler in New York City, March 1-2, 1955, will be the presentation of the Calvin W. Rice Lecture by SIR HUGH E. C. BEAVER, Chairman of the British Government Committee of Enquiry investigating the disastrous London smog of 1952. The meeting is sponsored by the American Society of Mechanical Engineers as part of the 75th Anniversary celebration of the Society, which held its first meeting in New York, in November, 1880. Since the Donora disaster of 1948 and the London smog of 1952, public interest in the subject of air pollution has grown steadily. The Society, recognizing the need for practical and technical experience to be focused on the problem, formed its Committee on Air Pollution Controls in 1949. This activity stemmed from earlier work by an ASME group which culminated in the publication of its model smoke law which forms the basis for most municipal ordinances on the subject. The 1955 International Congress is further recognition by ASME of the changing trends in the problem. Distinguished experts from all parts of the world will gather in New York to discuss the latest developments in the study and control of the air pollution problem. Among the sessions will be "Sulfur and its Gases" and "Gaps in the Available Knowledge on Air Pollution," both subjects to be discussed from various points of view. SIR HUGH BEAVER, who is Managing Director of Arthur Guinness Son & Company Limited, has held many responsible appointments, aiding the government in the study of special problems, among them on "new towns" and the "Building Industry Working Party." He has also held the offices of Director General and Controller General of the Ministry of Works. His new assignment which came in 1953 poses the enormous task of coming up with an answer to the cause and control of London smogs. The full significance of the 1952 London catastrophe was not immediately realized and Sir Hugh's committee was not appointed until July, 1953. The vigor of his attack is evidenced by the publication of a useful interim report before the end of that year. A final report is expected by the end of this year or early in 1955 and will form the basis of the lecture by SIR HUGH at the ASME meeting in March. The Calvin W. Rice Lecture was awarded SIR HUGH by the ASME in recognition of his many outstanding achievements in the engineering field. Created to honor the man who was ASME secretary from 1906 to 1934 and to further his ideals to increase understanding between the engineers of the various countries and to broaden the programs of Society meetings, the lecture has been awarded to distinguished engineers each year since 1934.

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